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OBSERVATIONS ON THE NATURAL HISTORY OF
DIVING BEETLES

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OUR predacious diving beetles of the family *Dytiscidæ* are fairly well known as museum species, but the study of their life histories and habits has been singularly neglected. A number of our genera and a few of our species occur also in Europe, and the natural history of some of these has been studied there; but practically nothing has been done in this line in our own country. Therefore the following observations on the habits and adaptations of the group may serve to direct attention to an unworked but interesting field.

Dytiscidæ are very common at Lake Forest, and are very accessible in a campus pond that lies almost under the windows of the biological laboratory. They illustrate very well the more obvious phenomena of adaptation, and have been much used by the senior author for that purpose with classes for a number of years. The material incidentally accumulated in that work, combined with special studies of life histories and habits made by the junior author during the academic year 1905-6, will constitute this paper.

The campus pond (locally known as the "Gym Pond") from which our material has mainly been obtained, is an artificial one, made by damming a short, spring-fed branch of one of the ravines that bound the campus. It has been in existence for many years, and conditions in it are now quite natural. It is some sixty meters long and about half as wide, and it attains a depth of four and a half meters in its deepest part, near the dam. Toward the other end it becomes shallow, and is filled with a dense and clear growth

of cat-tails (*Typha*). There is very little other vegetation in it anywhere, but the hollows of its shores become filled in autumn with oak leaves from the surrounding forest trees.

It is in the *typha* beds of the upper end of the pond, extending from the shore outward into water of about a meter in depth, that the diving beetles are commonly found. These beds cover an area of but little more than a square decameter, but in them we have found twenty-nine species of *Dytiscidae*, as follows,—

* <i>Laccophilus maculosus</i> Germar	<i>Hydroporus modestus</i> Aubé
<i>Laccophilus fasciatus</i> Aubé	<i>Hydroporus dichrous</i> Melsh.
<i>Laccophilus proximus</i> Say	<i>Ilybius confusus</i> Aubé
<i>Hydrovatus cuspidatus</i> Germar	* <i>Coptotomus interrogatus</i> Say
* <i>Bidessus lacustris</i> Say	<i>Agabus subfuscatus</i> Sharp
<i>Bidessus flavicollis</i> Lec.	<i>Agabus disintegratus</i> Cr.
<i>Bidessus affinis</i> Say	<i>Rhantus notatus</i> Fabr.
* <i>Calambus inequalis</i> Fabr.	<i>Colymbetes sculptilis</i> Harr.
<i>Calambus punctatus</i> Say	<i>Hydaticus piceus</i> Lec.
<i>Calambus dispar</i>	* <i>Acilius semisulcatus</i> Aubé
<i>Calambus acaroides</i> Lec.	<i>Acilius fraternus</i> Harr.
<i>Calambus nubilus</i> Lec.	* <i>Dytiscus hybridus</i> Aubé
<i>Calambus impresso-punctatus</i> Sch.	<i>Thermonectes basilaris</i> Harr.
<i>Deronectes catascopium</i> Say	<i>Graphoderes cinereus</i> Linn.
* <i>Hydroporus undulatus</i> Say	

No other *Dytiscidae* have been found at Lake Forest, except two that are occasionally cast up on the beach of Lake Michigan and that we have picked up from the drift line,— *Agabus semipunctatus* Kirby and *Cybister fimbriolatus* Say.

Distribution by Size and Depth of Water.— The seven species of the above list that are marked with a * are very common and easily obtained; and being fairly representative of the family, these were made the basis for the observations which follow. These fairly represent the striking difference in size that is found in this family coupled with an almost unparalleled uniformity of shape (Fig. 1.)

The shoreward distribution of these beetles corresponds roughly with their size: the largest are found in the deepest water, the smallest nearest shore. *Dytiscus* is usually found in the more open places between the outposts of the *typha* beds in the deepest

water, and *Acilius* is adjacent to it on the shoreward side, although both (as well as the following species) may range shoreward foraging. *Coptotomus* abounds in water about a third of a meter in depth, and loves to disport itself in the narrow aisles between the *typha* clumps. *Laccophilus* dwells amid the fallen stems and trashy accumulations nearer shore, and is less in evidence in open water. *Hydroporus* and *Cœlambus* love the shoals into which one can look down while sitting on the bank, while *Bidessus* clings to the very shore line: it has nearly always been found by us within a few inches of dry land.

The larvae of these forms show, likewise, a general distribution in depth corresponding to their size although the larvae keep more

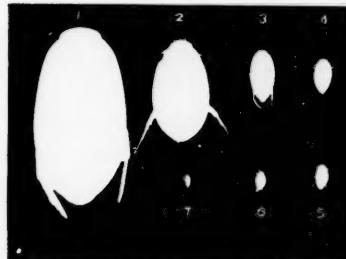


FIG. 1.—Silhouette print of seven adult diving beetles, illustrating the uniformity of shape and disparity of size found in the family Dytiscidae: natural size. 1, *Dytiscus hybridus* Aubé. 2, *Acilius semisulcatus* Aubé. 3, *Coptotomus interrogatus* Fabr. 4, *Laccophilus maculosus* Germ. 5, *Hydroporus undulatus* Scy. 6, *Cœlambus inequalis* Fabr. 7, *Bidessus lacustris* Say.

closely to cover of vegetation than do the adults. *Dytiscus* larvae are found chiefly in the more open vegetation in the deeper water: *Bidessus* larvae, at the shore line: and the others ranged between. It must not be understood that there is any such definite and sharply limited zonal distribution as aquatic plants on such a sloping shore often exhibit: that is not to be expected in animals possessed of such excellent powers of locomotion: we have meant to indicate merely the favorite haunts of each species, and the general correspondence between size of beetle and depth of water.

The accompanying table gives a more precise statement of the difference in size of the seven common forms of adult beetles already mentioned. The length was measured with a metric

caliper rule. Weight was determined with a chemical balance. Live beetles were weighed inclosed in envelopes of absorbent paper to remove the excess of moisture; then the weight of the paper with its contained water was deducted, and the remainder was divided by the number of the beetles used. By this means fairly accurate average weights were secured. In the other columns of the table are expressed with much less accuracy the comparative excellence of these seven beetles with respect to their different modes of locomotion.

Name	Length	Weight	Order of excellence in		
			Swimming	Walking	Jumping
<i>Dytiscus hybridus</i>	27.6 mm.	1.303 grams	1	7	5
<i>Acilus semisulcatus</i>	14.1	.1936	2	6	2
<i>Coptotomus interrogatus</i>	7.9	.033	3	5	3
<i>Laccophilus maculosus</i>	5.5	.0142	4	4	1
<i>Hydroporus undulatus</i>	4.0	.010	5	3	4
<i>Coelambus nubilus</i>	2.9	.0032	6	2	6
<i>Bidessus lacustris</i>	2.0	.0005	7	1	*

The Activities of the Adult Beetles.—There is a very marked difference in the swimming powers of these beetles. Such forms as Cybister probably manifest the highest efficiency in the family. The long beautifully fringed hind legs are moved synchronously; the flattened and fringed tarsi and the blade-like lower tibial spur meet the water squarely, and each stroke sends the body forward several times its own length; whereas the rapid strokes of the scantily fringed feet of some of the lower members of the family, little modified in their motion from that employed in walking, produce individually but little result in forward progress. In arriving at an estimate of the swimming capacity of the seven forms listed in the above table the actual distance traversed per second was determined, and also the distance for each stroke of the swimming legs. In order to make just allowance for differences of size, this distance was expressed in terms of length of body. There was some difficulty in making these measurements, owing to the extreme rapidity of movement of the legs in the case of some of the smaller beetles, and owing also to the irregularity of their movements. In general, the ability to hold a straight course, to control equilibrium in turning, and to economize effort by elimina-

* Could not be induced to jump at all.

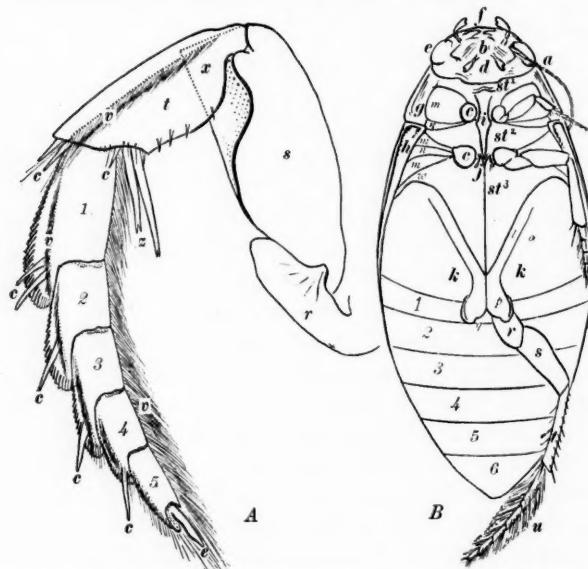
tion of useless motions of the fore legs was also taken into account and the estimated average is expressed in the table. Beetles fresh from the pond were used in every case.

Walking was compared by turning the beetles out upon a long sheet of blotting paper before a window, and allowing them to run toward the light. Excellence at walking was estimated not so much by speed as by ability to support and propel the body upon all of the feet. The greatest speed across the paper was occasionally attained by *Dytiscus* but it was not walking: it slid along on its belly, with its hind feet high in air, its front feet reaching forward, catching the hooked claws and drawing the body after. *Bidessus*, however, gets up on its feet and runs like a ground beetle, freely using all its tarsi. There is in *Bidessus* none of that flopping and floundering that characterizes the progression of the more specialized forms when out of water.

Jumping, in this table, covers any sort of sudden springing forward in air. The hind feet alone may be used very effectively, as in *Laccophilus* which is by far the best jumper of the lot, but they may also be assisted by the wings. It is not an uncommon thing to see at the pond a *Laccophilus* suddenly emerge from some trash floating on the surface and instantly spring into the air, using its wings as well as its legs, and then drop on the water and disappear instantly beneath it: for *Laccophilus* can take flight very quickly. The slow and lumbering start of most members of the family, is not at all characteristic of this beetle. The superior jumping powers of *Laccophilus* are explained in large part by the structure of its legs; especially their equipment of tarsal spines (Fig. 2 A).

The order of excellence in swimming and walking in this series of beetles has been determined by classes of students at Lake Forest for a number of years, and it has always been found as it stands in our table. The suspicious regularity of the figures raised some doubts in our minds as to their correctness: so the junior author went over the work of determining them carefully anew, with the result that they appear to be entirely confirmed. Doubtless such close correlation between size and excellence of swimming would not hold everywhere among the *Dytiscidæ*. Some of the smaller, more convex forms are very highly specialized. Our

series of seven selected at first solely on account of availability and abundance happened to be a most excellent one for illustrating the law of specialization. Nothing could be clearer than that, in this series, increasing fitness for locomotion in water accompanies increasing unfitness for locomotion on land.



beetle (as, for example, *Calosoma*) with any of the higher *Dytiscidae* (such as *Dytiscus*) we shall see some marked contrasts in appearance, and some indications of the main lines that have been followed in the adaptation of the latter to aquatic life. The body of *Calosoma* is loosely jointed; its surface is provided with sensory hairs and is sculptured; its antennæ are prominent and hairy, and its feet are long and adjustable to every inequality of its path. *Dytiscus* on the contrary is compact of body and evenly contoured, pointed at both ends and naked, with slender hairless reversible antennæ, and stiff oar-like hind feet. There are three main features of this adaptation, namely an increased rigidity of the body, diminished resistance to the water, and an increased swimming efficiency of the hind legs.

The increase in the rigidity of the body has been accomplished by the compacting and coadaptation of the parts of the external skeleton. Close conjunction has been effected between the head and prothorax (through immersion of the head into the front of the latter); between the several segments of the thorax; between the elytra and the sides of the abdomen; between the front margin of the elytra and the prothorax; and between the two elytra along the dorsal suture: this and the joining with the sides of the abdomen combine to make the air chamber inclosed beneath the elytra water tight. These coadaptations which distinguish the *Dytiscidae* from terrestrial Coleoptera have been well recognized by systematists, and are especially well discussed in Sharp's great monograph of the family *Dytiscidae*.¹ Rigidity is demanded in the body of a diving beetle as in the hull of a boat. The means of securing it are most noteworthy in those parts where in other beetles we find great flexibility, as between the first two segments of the thorax. This particular articulation can be fully seen and appreciated only in a disarticulated beetle, some of the coadaptive structures being more or less concealed by parts external to them. It is technically described by Dr. Sharp (*l. c. p.* 219) as follows:

"The coadaptation of the various parts of the posterior aspect of the prothorax, to corresponding parts of the after-body and base of the wing cases is extremely perfect and very complicated; proceeding from below upward, we have first, the prosternal process (Fig. 2 *B, i*) stretching beyond the meso-

¹ On Aquatic Carnivorous Coleoptera or *Dytiscidae*. *Trans. Roy. Dublin Soc.* for 1882.

sternum to be received in a metasternal groove; directly above the prosternal process we see a considerable protuberance or prominence which fits into the fork of the mesosternum; then come the posterior aspects of the coxae, which fit into facets on the face of the mesosternum, and on a still higher level we have the transverse bridge closing the coxal cavities which fits into the interior of the mesosternum, while on the upper surface we find that the base of the mesothorax and scutellum are shaped so as to allow the hind margin of the pronotum to overlap and accurately fit them, while the shoulders of the wing cases are prominent, and rest on an expansion of the posterior face of the pronotum which is beautifully sinuate and emarginate to facilitate the coadaptation. This joining is so perfect in the higher forms, such as *Cybister*, that if after the prothorax has been detached from the after-body an attempt be made to replace it in its natural position, this is very easily effected; and it will then be found that the prothorax retains its position in spite of considerable efforts being made to dislodge it."

A diminished resistance to the water has been brought about in many ways,¹ notably by the rounding of the contours of the body especially at the neck and shoulders, so that it assumes a boat shaped form†; by the depression of the eyes†; by the loss of hair† and sculpture; by reversal of the antennæ; by recession of the fore and middle legs into the concavities beneath the thorax at the sides; and by the flattening of the hind legs in the horizontal plane†.

The increased swimming efficiency of the hind legs has also been brought about in many ways, the seven most striking of which are as follows,— the flattening down and soldering fast of the hind coxae (Fig. 2 B, *k k*) to the ventral surface of the metasternum, transforming what is in other beetles a movable joint into a remarkably rigid supporting base; the bringing of the basal joints of the leg into one plane of action, limiting their movements, but increasing the range of motion in the one horizontal plane; the development of braces at the joints to further limit motion to one plane, making the leg more rigid and oar-like; the shortening of the proximal joints of the leg†; the lengthening of the joints of the tarsus† accompanied by the flattening of these joints and occasionally of the tibial spurs as well; the development of swimming fringes

¹ The features designated by a dagger in this and the following paragraph appear to be exact parallels of aquatic adaptations in mammals, as stated in Dr. Osburn's interesting article in the *American Naturalist* for October, 1903 (vol. 37, pp. 651-665). In many other respects it appears that by diverse means analogous results have been attained. That the changes in body are not more directly comparable in the two groups is due to the very great differences in the nature of the supporting skeleton.

in the thin lateral margins of the tarsus; the recurvature of the tarsi to a more dorsal position, in line with the motion of the center of gravity of the body †; and finally the loss of the hind claws†.

The modifications having to do with the taking and storage of air are much less obvious. They consist in the adjustments of the margins of the elytra (already mentioned for their compacting and strengthening function) which tend to make a water tight air-compartment; and in the slight modification of the tracheal system in a few members of the family (Dytiscus, etc.) manifest in the enlargement of the hindmost abdominal spiracles to several times the diameter of the other spiracles. The respiratory apparatus of terrestrial beetles has been evidently fairly adequate, and the main problem has been that of getting through the water with sufficient ease and speed to capture prey and to escape from enemies.

The Larvæ Studied.—Five species of larvæ of Dytiscidae were kept under observation. Unfortunately but one of these (*Hydroporus undulatus* Say) was reared to the adult beetle. The others are here named tentatively, it being possible to make a supposition as to the genera to which they belong, based on the known fauna of the Gym pond, on their size, and on their likeness to known European forms. The largest larvæ encountered (41 mm. long) were those of Dytiscus. These are of the sinuous spindle-shaped form, well known from being figured in every entomological text book. We found them in May in great numbers, feeding on *Corethra* pupæ in the deep narrow straits of open water between standing aquatics, but they are so well known and they require such quantities of live food daily, that we did not attempt to rear them. Of still more snaky form and with an equally good development of swimming fringes on legs and the sides of terminal abdominal segments is the agile larva of *Acilius*. It is an exceedingly graceful creature, and has a remarkable capacity for dodging quickly when approached. Our specimens of this form were young (15.5 mm. long) and their nurture had to be abandoned before any of them had transformed.

The larvæ which we have referred tentatively to *Coptotomus interrogatus* (Fig. 3) are but poorly adapted for aquatic life: they are much more like primitive ground beetle larvæ of the family

Carabidæ. We obtained numerous specimens in the fall of 1905 when our cages were first started, and these furnished our early experience. The first lot collected, kept over night in a small vessel, ate each other; in the morning but one remained. The second lot, kept over night in a large vessel with plenty of proper food, did exactly the same. Then we made a screen cage with separate compartments, set it in an aquarium and put our third lot into it, one larva in each compartment. These then climbed

out of the water and over the partitions and ate each other as the others had done. They did not mind a little ramble in the open air at all. By this time we had learned the necessity of covering the top as well as the bottom of each compartment: but unfortunately we were not then able to find any more larvae. This is the more regrettable because no larvae in this endemic American genus have been made known. A description of the larva is appended to this paper.

We were fortunate in finding in the spring of 1906 grown larvae of *Hydroporus undulatus* Say (Fig. 4), and in rearing them. These were taken from the pond May 20th and were kept in shallow water in a flat bottomed white dish containing a few dead leaves and bits of typha stems. Showing nothing of the disposition of the larger larvae to eat each other, we left them together in

the dish and fed them with small fresh pieces of damselfly larvae. On May 29th four of the larvae were found inactive and curled up on their backs on the bottom of the dish. These were placed on damp sand in a dish covered so as to be perfectly dark. They did not spin, nor make a cell, nor even move from the positions in which we placed them, but on June 2nd, two of them were found transformed to soft white pupæ of the form shown in Fig. 5 and two

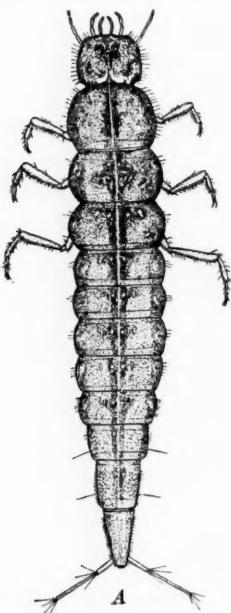


FIG. 3.—Larva of *Coptotomus interrogatus*?

days later the other two had transformed. On June 8th, the first one transformed to the adult beetle. A little later adults of the same species could be collected commonly from the edges of the pond.

The minute larvae of *Bidessus*, apparently grown, were found so near the close of our work that there was no time for attempting to rear them. They are here referred to the commonest species of the genus from the same habitat, *Bidessus lacustris*.



FIG. 4.—Larva of *Hydroporus undulatus*.

Habits of the Larvæ.—The larvæ, like the adults, are all carnivorous. The larger ones are all cannibals: only *Hydroporus* and *Bidessus* among those we have taken, when kept together refrain from eating each other. We fed the largest larvæ on damselfly and mayfly nymphs, and those of medium size on

Corethra larvæ, these being the most abundant forage available. For all but the smallest species the manner of feeding is much the same. The prey is seized alive by the fore legs and the mandibles are instantly thrust into it deeply, and it is sucked until nothing remains but the empty skin. For the small *Hydroporus* larvæ we were unable to supply living prey of suitably small size: so, pieces of damselfly larvæ freshly cut up for the purpose, were used. These were seized between the long frontal horn



FIG. 5.—Pupa of *Hydroporus undulatus*.

(Fig. 6) and the upcurved mandibles, sucked for a little while, then dropped, to be returned to at intervals and seized and sucked again.

The swimming habits of the different larvæ are remarkably different. *Coptotomus* (Fig. 3), having little development of swimming fringes, makes very violent and inefficient movements

of the legs and abdomen in swimming. When approaching the surface of the water the head is upward and the body advances by a succession of irregular shifts (Fig. 7 A, s). It rarely takes a direct course to the surface, and in water of more than a few inches depth, it has great difficulty in reaching the surface by swimming. It can remain below for a considerable time. Of half a dozen specimens transferred to a fresh aquarium and watched, the first to reach the surface came up in about four minutes, but went down again at once: the first to remain at the surface taking air, rose after twelve minutes: several did not rise for at least seventeen minutes. In taking air this species hangs vertically from the surface with legs limply extended, and with caudal cerci outspread

upon the surface film (Fig. 7 A, t). When it leaves the surface, it swims downward head first in an indirect sinuous course. The tail appears not to be used at all as a fin in swimming. The larvae of *Dytiscus* are possessed of an excellent swimming fringe along

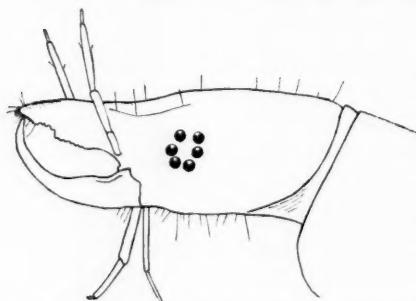


FIG. 6. — Head of larva of *Hydroporus undulatus* seen from the side.

either side of the terminal abdominal segments, and they use their tails continually in swimming, lashing them violently back and forth, up and down. They swim to the surface head upward (Fig. 7 B, v), but quite as often they float slowly upward with both head and tail elevated, the former a little in advance, and with the body bent in a wide U-shaped curve. Usually when floating thus, bubbles of air may be seen sticking to their bodies. While taking air they retain this curved position (Fig. 7 B, w), the top of the head as well as the caudal cerci resting in the surface film. These larvae are powerful members of the natural society in which they live, and are much less easily frightened than other species. One of them that had been fed regularly for a few days would allow its back to be stroked gently with a pencil, and not until poked violently would it swim away: then it would

swim very rapidly, as if in sudden alarm, with quick wriggling movements of its body and tail.

The larva of *Acilius* although much like that of *Dytiscus* in general appearance and in the possession of excellent swimming fringes, is very different in its habits. It has a peculiar way of swimming toward the surface tail upward, in a sinuous course as indicated in the diagram (Fig. 7 C, x) its progress being accomplished by very slight movements of its legs. Often one will start from the bottom swimming forward, then circle about horizontally once or twice, and finally rise to the surface, tail upward, as just described. This species swims very rapidly, twisting and turning its long slender body like a snake. When disturbed it

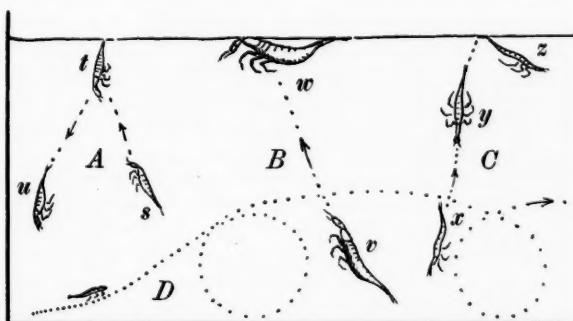


FIG. 7.—Diagram of swimming habits and attitudes of dytiscid larvae. A, *Coptotomus interrogatus*. B, *Dytiscus hybridus*. C, *Acilius* sp. ? D, *Hydroporus undulatus*.

darts with a peculiar indescribable motion of the whole body away from the point of disturbance. Sometimes it makes just one quick dodge, and sometimes it goes through a series of wriggling movements so swiftly executed that the eye cannot follow them. This dodging feat must be of great advantage in avoiding enemies.

The larva of *Hydroporus* (Fig. 4) has only a scanty development of swimming fringes on its legs, and its tail is used merely as a rudder. It crawls much and swims little. It has a boomerang-shaped body, which when projected through the water, has a corresponding motion. It circles about in a vertical plane, its back to the outside of the curve, as indicated in the diagram

(Fig. 7 *D*). Placed in a deep vessel of clear water the *Hydroporus* larvae spend much time swimming about in this manner, very rarely rising to the surface. During various periods of observation, none were seen to remain at the surface taking air: and during about an hour and a half of continuous observation of half a dozen specimens together in a large beaker, not one of them rose to the surface. When kept in a shallow dish of water with plant fragments, they spent much time crawling about on the bottom, creeping beneath dead leaves, or hiding in the hollows of the *typha* stems.

Supplemental descriptions of hitherto unknown larvae of Dytiscidae

1. **Coptotomus interrogatus** Fabr. (supposition). Length of larva: 17-18 mm., cerci 2 mm. additional, greatest breadth 2.5-3.0 mm.

Body elongate, rather stout anteriorly: head narrower than the prothorax, which equals the other thoracic and the first four abdominal segments in breadth: terminal segments of the abdomen tapering. General color brown above and on legs; below, paler.

Head depressed, the sides parallel for more than half its length, from the eyes to the spinous margined hind angles, behind which it is constricted to a short neck. Mandibles stout, prominent, channeled nearly to the base (Fig. 8, *g* and *i*). Maxilla with two curved spines upon the inner face (Fig. 8, *a*) in a close fringe of short hairs, a sub-cylindric end segment, a four-jointed palpus and single terminal and dorsal setæ. Labium (Fig. 8, *e*) simple, its body trapezoidal, the anterior margin double-edged and the edges beset with fine short spinules, the second joint of the palpus bearing internally a long fine seta. Antenna (Fig. 8, *d*) four jointed, simple.

The general color of the head above is brown, with a pair of obliquely placed transverse pale marks between the bases of the antennæ; behind these, two small clusters of pale dots with yellow (marks between them and a pair of larger yellow dots behind them. On the occiput, a pair of larger ff. marks more or less confluent with the yellow of the hind margin stands between two more scattered clusters of pale dots, which extend in a line forward and outward to the eyes: outside these lines of dots is a yellow oblique stripe on each side above the spinous margined hind angles.

The prothorax is but little longer than broad, its sides are broadly rounded and its anterior end is constricted to form a short neck. In coloration it is brown above, with a median double row of more or less confluent pale dots abbreviated before and behind and not reaching the ends of the segment, and with a few widely separated, elongate hiero-

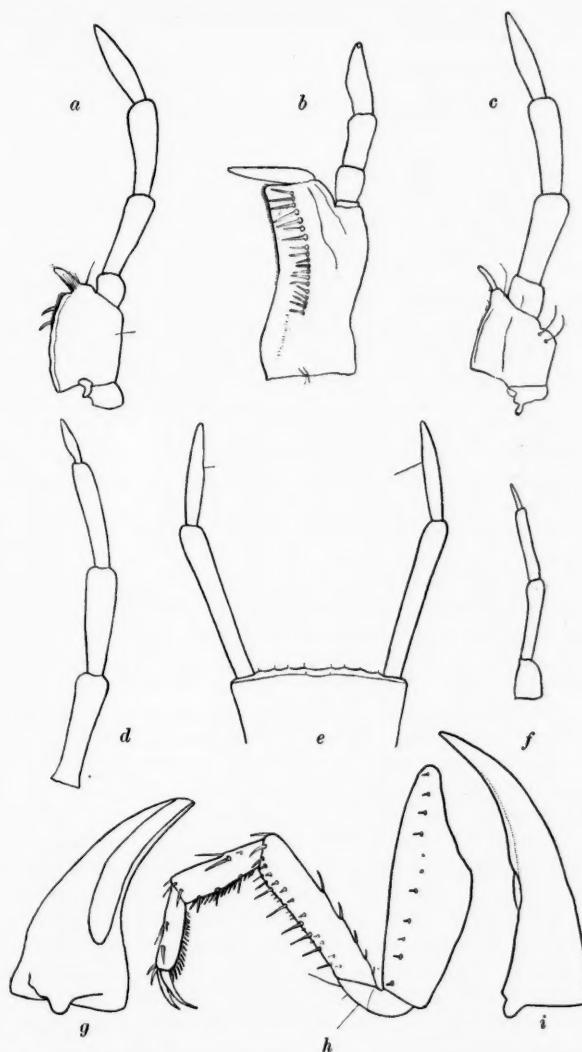


FIG. 8.—Structures of larvae of Dytiscidae. *a*, maxilla of *Coplotomus interrogatus*? *b*, maxilla of *Acilius* sp.? *c*, maxilla of *Coplotomus longulus*? *d*, antenna and *e*, labium of *Coplotomus interrogatus*? *f*, maxilla of *Hydroporus undulatus*. *g*, inner aspect of mandible, *h*, fore leg and *i*, outer aspect of the mandible of *Coplotomus interrogatus*?

glyphies on the disc each side. On the succeeding segments, which are about two thirds as long, there is only one pair of pale submedian dots and these are placed close behind the anterior transverse carina: and there are a few pale markings outside these on each segment, the innermost one of which each side becomes resolved into a single longitudinal dash on the abdominal segments. All these markings disappear on the hindmost segments, which are uniformly deeper brown. The legs are brown with narrow darker lines across the tips of femora and tibiæ. The spiracles are set in the uninterrupted lateral margin of the dorsal shields on the middle abdominal segments.

The basal abdominal segments are of nearly equal length. The length increases slightly successively on segments 4, 5 and 6 and rapidly on 7 and 8, each being one half longer than the segment preceding it. There are a few slender setæ about the lateral margins of all the body segments except the hindmost, and that segment is thickly beset all over its dorsum with short stout spinules. The respiratory tubercle is short and obtusely truncated: viewed from the side it is conspicuously and obliquely prolonged over the bases of the cerci. The cerci are about as long as segments 7 and 8 together, two jointed, the second joint being about three times the length of the basal one: at the tip of the basal segment are two or three slender setæ, and at the tip of the terminal one four more.

2. *Coptotomus longulus* Lec. (supposition). While this study was in progress the larvae of a second species, so closely similar that it probably belongs in the same genus, were received from Professor T. D. A. Cockrell, collected by him from the Gallinas River, Las Vegas, N. Mexico on the 12th of Jan. 1902. These are like the ones just described in size, and in general coloration, though the color pattern is less sharply defined. They differ in lacking the curved spines from the inner face of the maxilla (Fig. 8, c) and in the relative length of the segments of the cerci, the second being hardly twice the length of the first.

3. *Hydroporus undulatus* Say. Length 6 mm.; cerci, 1 mm. additional; greatest width about 1 mm.

Color brown above, whitish beneath. A narrow middorsal line of pale yellow extends from the middle of the head backward the length of the body: it is somewhat interrupted by the dark brown posterior margins of the middle abdominal segments. On the front of the head this pale line is dilated to include three brown spots: a pair of U-shaped spots between the eyes, the arms of the U's extended backward, and a median spot on the base of the rostrum. There is a lateral row of large pale spots beginning on the side of the head, where it encircles the eye, and ending on the eighth abdominal segment. These spots are elongate and jagged on the inner margin on the thoracic segments but rounded and diminishing in size posteriorly on the abdominal segments. The antennæ and legs are pale. In the brown of the rear of the head between the median

and lateral spots are three minute yellow dots each side: these are often confluent.

The dorsal plates of all the body segments are thinly clad with slender fragile setæ: the hind margin of each abdominal segment bears a fringe of stouter setæ: the fringe is much shorter than the length of the segment.

The cerci are slender, tapering, longer than the seventh and eighth abdominal segments taken together: they are studded externally with thin and scattering setæ and bear at the tip a little cluster of a few setæ, the central one of which is much stouter than the others and appears as a prolongation, or as a second tapering cercal segment.

The rostrum (Fig. 6) is as long as the head, broad and obtusely rounded at the tip, indented just beyond the middle of each lateral margin, with the broader more flaring edge behind the indentation fringed with excessively minute and slender setæ of which there are several transverse rows that extend across the dorsal surface.

The coxae are somewhat longer than the femora. The femora, tibiae and tarsi are armed with stout spinules beneath, and tibiae and tarsi bear also scanty fringes of longer hairs externally.

The mandibles are long and sickle shaped, and are perforated nearly to the upturned tips, which rest just beneath the tip of the rostrum. Maxillæ greatly reduced, laciniaæ and galeæ being wholly wanting (fig. 8 f). Labium projecting, mentum narrow, trapezoidal, widened anteriorly, the slender nearly naked two-jointed palpi arising from the square cut front border near the outer angles: at the middle of the terminal joint of palpus are two slender setæ and four or five arise about the base of the first joint.

4. *Bidessus lacustris*. Length 3.5 mm: width .6 mm.

Color grayish brown, faintly marked with grayish yellow, the latter color predominating on the head and on the hinder abdominal segments. Body beneath and all appendages pale. The brown of the head and prothorax forms a large dorsal X whose anterior arms end between and close to the eyes, whose large posterior arms reach backward beyond the middle of the prothorax and are incurved at their tips. Between them arises the stem of a T-mark whose top bar occupies the hind margin of the prothorax. Meso- and meta-thorax with an obscure brown mark each side. Abdominal segments suffused with brownish, and having an indistinct divided pale transverse bar across each except the last.

The respiratory tubercle of the eighth abdominal segment is triangular pyramidal, and continues the slope of the sides of the segment to a subacute tip, and is about half as long as the body of the segment. The cerci are slender and tapering. They are armed with a pair of long setæ externally at one third their length, opposite the tip of the respiratory tubercle, another single external seta at two thirds their length, and at the tip is another external one close beside two internally placed and

similar ones, and a central stouter seta that continues the taper of the appendage and is attenuate to an excessively slender tip.

The general pubescence of the body is short, dense and scurfy: that of the legs is shorter and stouter. On the hind borders of the abdominal segments there is hardly any differentiation of apical fringes.

The rostrum is longer than the head, broad and obtusely rounded at its tip, where it bears a fringe of very fine close-set setæ, suddenly broadened opposite the bases of the antennæ where the heavy pubescence of the body begins, and toothed beneath at midway the length of its lateral margins. The mandibles are somewhat constricted just before the tip and bear a ring of scattered setæ about the constriction.

This larva differs from that of *Hydroporus* most markedly in the dense pubescence of its body, in the possession of longer tarsal claws — claws as long as the tarsus itself, and in the continuity of outline of the sides of the eighth abdominal segment with the respiratory tubercle, there being no constriction setting off the latter at its base.

BIOLOGICAL LABORATORY
LAKE FOREST COLLEGE

HABITS OF THE SHORT-TAILED SHREW, *BLARINA*
BREVICAUDA (SAY)¹

A. FRANKLIN SHULL

INTRODUCTION.

In January, 1906, in a low tract of land near Ann Arbor, Professor Jacob Reighard found upon the snow a number of heaps of snails of several species of the genus *Polygyra* (Fig. 1). At his suggestion and under his supervision I undertook to find what had heaped these shells and to pursue any further studies suggested by the discovery. I am also indebted to Mr. Bryant Walker for identifying a number of snails.

The heaps contained from two or three to more than a hundred shells. During the whole period of observation five species were found represented,—*Polygyra albolabris*, *P. multilineata*, *P. profunda*, *P. thyroides*, and *P. fraterna*, in the approximate ratio of 300: 250: 30: 1: 8. On several successive excursions the number of shells in individual heaps was counted, and it was found to vary; shells had either been taken away or added. No marks were visible in the snow to tell how the shells had been moved, but there was invariably the opening of a small burrow near the heap. My problem was to discover what animal was moving the snails, and also something of its habits.

FINDING THE SHREW.

The presence of a burrow at each heap and the absence of marks in the snow suggested that the occupant of the burrows was moving the shells. To determine this point, bacteria dishes were inverted over each of several of the heaps of snails together with the adjacent burrow. The snails were found to be moved just as before. A further test was made as follows:—A heavy wire

¹ Contributions from the Zoological Laboratory of the University of Michigan No. 112.

was passed through a spool and bent down at the ends in the form of an inverted U. The sharpened ends of the wire were thrust into the ground. The spool was held in such a position that a thread unwound from it could easily pass into the burrow. On the reel thus formed were wound several yards of carpet thread, to the end of which a snail was tied by means of a hole pierced through its shell just back of the lip. The shell was then placed near the opening of the burrow. The thread was marked at intervals so that it would be possible, without first finding the shell, to determine how much had been reeled off. At the next visit to the heaps the thread was found extending into the burrow for about a foot. The shell was still fast to the string, but had been broken open and the snail was gone.

Now that I knew where to look for the animal, I began to set traps. At one place there were two large heaps of shells about a meter apart, each near a burrow descending abruptly into the ground. Between these was a well worn path in the snow at the surface of the ground. Into this path a steel wire trap was sunk by digging out a bit of the earth, so that the trigger of the trap was on a level with the bottom of the trail. No bait was used. At my next visit the trap contained a short-tailed shrew, *Blarina brevicauda*. Many of the snails had been removed, showing either that the animal had for some time escaped the trap, or that another shrew had carried on the work after the first had been captured.

My work was then ordered according to the following plan: (1) To discover as many heaps of snails as possible in different situations, and to record minutely the changes in location of the shells above ground; (2) As soon as the frost had thawed out of the ground, to excavate the burrows and search for nests; (3) To capture in the meantime one or more shrews and confine them in the laboratory; and (4) To make various psychological studies in the laboratory and in the field.

OBSERVATIONS ON THE HEAPS OF SNAIL SHELLS.

All my field observations were made in Steere's swamp, a tract four miles south of Ann Arbor. It was here alone that the heaps of snails were found, though search was made for them at other

places where the shrew had been taken. The soil of this region is rich black peat, at many places in a rather early stage of decomposition. The groundwater level in spring occurs at a depth of only 15 to 20 cm., so that after even moderate rains the water stands at the surface in places for several days. Several ditches have been dug through the swamp. Near these the groundwater level sinks gradually to the level of the water in the ditch, which was usually 60 to 70 cm. below the surface at the season when my observations were made. According to old settlers, the region



FIG. 1.—A heap of 19 snail shells near the opening of a burrow of *Blarina brevicauda*. This burrow is not visible, the large one beyond the heap belonging to another animal. The shells are in a slight depression where the snow has not melted.

was formerly occupied by tamaracks, black ash, and willows. Since it was cleared a few years ago, nettles, goldenrod, and sumac, with here and there a thicket of black ash, willows, elder, and raspberry, have taken the swamp.

Apparently the region favors the growth of snails, for they are abundant. Many live ones were found after warm weather had set in, and large numbers of empty shells were scattered over the surface. Within two areas containing the principal thickets and goldenrod patches of the swamp, each less than 150 meters in radius, there were found, by careful search, a total of over forty heaps of shells. The larger portion of these was being moved. Of those shells that were not being moved, a number were cracked.

They may have been broken before the shrews began collecting them; they may have been accidentally cracked in transportation; or the shrews may have broken them purposely, to render the snails immobile. This effect was produced by compressing some snails in a vise until their shells were cracked much like those in the field. These snails were placed with uninjured ones on moist earth in a warm situation; the latter were soon crawling about. Those with broken shells never came out although for three weeks they contracted in response to thrusts with a stick, showing that they were still alive.

The shells at the various heaps were either occupied or empty. The number of both sorts was being increased in certain heaps which were receiving additions. When, at another time, shells were being removed from these heaps, only the number of occupied shells was diminished, whereas that of the empty shells remained the same. To determine whether this distinction occurred regularly, a considerable portion of the shells was numbered. The figures were placed near the base of the columella, since in all the broken shells that had been observed up to that time this portion remained intact. At each visit, the numbers of the shells at individual heaps were recorded, and when they were not too numerous, their relative position was carefully mapped. A record was kept of the condition of the shells, whether they were occupied or empty, entire or broken, at the time of numbering. As new shells were added to the heaps, they were numbered.

From Feb. 15 to Apr. 7, 144 shells found in the field were numbered. Of these, 99 were occupied, and 45 were empty, most of the latter being unbroken. To increase the number under observation, 25 snails that had been killed in formalin and then transferred to alcohol were added to the various heaps where the number of shells was found to vary. At the end of this period of more than seven weeks, the records showed that the following disposition had been made of the shells:

TABLE I. Showing the number of occupied and empty shells, also snails killed in formalin, which were removed from the surface, and the number left at the surface.

Condition of shells.	Number of shells.	Number of shells removed.	Number of shells left.
Occupied	99	76	23
Empty	45	2	43
Formalin	25	7	18

It is seen that most of the occupied shells were removed, although but few of the empty ones were ever taken away. The formalin snails show neither extreme, though the majority were untouched. Apparently the shrews have some method of distinguishing between an empty shell, a normally occupied one, and a snail killed in formalin. Experiments to determine the basis of this distinction are described under the head of Psychology.

The numbering of the shells served also to show the relation between the activities of the shrews and climatic conditions. The climatic data are from the Observatory of the University of Michigan. Humidity was not recorded but it seems hardly probable that the absolute humidities possible at the low temperatures that prevailed would have any marked effect. The temperature readings on days when field trips were made, and the observations on the shells for a period of seven weeks are given in Table II. The shells here included were brought to the surface of the ground at 21 different points on an area not more than 8 meters in diameter. Two shrews were eventually captured at this place, and subsequent excavation of the burrows within this area revealed but one nest. I have concluded, therefore, that the heaping up and removal of all these shells was probably the work of a single pair of shrews. My field trips were made sometimes in the forenoon, sometimes in the afternoon. I nearly always visited this small area first, since it lay on that side of the swamp nearest Ann Arbor. I then passed on to the more distant parts of the swamp, and returned to the same area some three hours later, again carefully noting the arrangement of the shells. In only one instance did I find that any shells had been moved during the three hours, and then three shells were brought to the surface in the forenoon. From these facts I have concluded that most of the shells are moved at night. In the table, therefore, I have given the minimum tempera-

ture of the night, rather than the maximum or the average. The Fahrenheit scale is retained as given in the weather records. The snails killed in formalin which were placed at the burrows in this area are not included in the counts.

TABLE II. Showing the number of shells at the surface in an area 8 m. in diameter, and the minimum nightly temperature, for a period of over seven weeks.

Date.	Minimum tempera- ture °F	Number of shells at surface.			Change in total shells since last visit.	Change in min- imum temper- ature since last visit.
		Occupied	Empty	Total		
Feb. 15	2	61	13	74	...	...
	20	30	32	49	— 25	+32
	22	29	28	46	— 3	— 1
	24	38	33	51	+ 5	+ 9
	27	14	146	169	+118	—24
Mar. 1	23	118	24	142	— 27	+ 9
	2	26	...	...	...	...
	3	31	...	...	...	...
	4	25	...	...	...	...
	5	23	...	...	...	...
	6	19	72	97	— 45	— 4
	8	32	52	77	— 20	+13
	10	25	59	84	+ 7	— 7
	13	16	56	81	— 3	— 9
	15	14	57	82	+ 1	— 2
	20	16	60	85	+ 3	+ 2
	24	8	59	86	+ 1	— 8
	27	35	29	61	— 25	+27
	31	25	26	58	— 3	—10
	Apr. 3	35	24	56	— 2	+10
	7	37	16	48	— 8	+ 2

As in Table I it is seen that the number of empty shells was never diminished, showing that once the empty shells were brought to the surface they were not ordinarily moved again. Throughout the seven weeks there is a steady increase in the number of empty shells. If the last two columns be compared, it is observed that on ten of the sixteen days the change in temperature and the change in the number of shells are of opposite sign,—that is, with a rise in temperature shells are removed and vice versa. These ten days include all the most marked temperature changes, namely, those on Feb. 20, Feb. 27, Mar. 8, and Mar. 27. Similar to these are the changes for Mar. 1 and Apr. 3. The conspicuous exceptions are Feb. 24 and Mar. 31, when, though the temperature

changes are marked, the change in the number of shells is of the same sign as the temperature change. Further, with the one exception of Mar. 6, all the considerable changes in the number of shells occurred at times when the temperature changes were of opposite sign. On this date there seemed to have been a marked removal of shells into the burrows, while at the same time the temperature had fallen. However, five days had elapsed since the last preceding visit. In this time there had not been a steady decline of the temperature; but the temperature had risen 8° between Mar. 1 and Mar. 3, and then fallen 12° from Mar. 3 to Mar. 6. Had I observed the shells on Mar. 3, the number of shells might have been much smaller than for Mar. 1, and then increased to Mar. 6. This seems especially probable since some of the individual heaps showed an increase on Mar. 6, and others a decrease. The decreasing effect of the rise of temperature prevailed.

NESTS AND BURROWS

The Burrows.—The record of the snails was closed Apr. 7. Though a few occupied shells were still above ground, the weather was then so warm that several of the snails were found crawling about. Records of their transportation were untrustworthy after that time, and were discontinued. By this time the frost was in large measure out of the ground, and excavation of the burrows was begun. Two methods were employed. Where the ground was not very wet, flour was sometimes blown into the burrows with a small hand bellows. The burrow was then carefully opened as far as the walls were whitened, and more flour was blown in. If the ground were wet, the flour soon became moistened and lost much of its whiteness. A more successful method was to pass a rather stiff rubber tube into the burrow to keep it open while the spade was being used.

Some difficulty was experienced at first in determining which burrows were those of the shrew. The runs at the surface in which the shrew was trapped looked exactly like those of the meadow vole, or field mouse, *Microtus pennsylvanicus*. Moreover, I have seen *Microtus* enter burrows that descended abruptly

into the ground, so that it could not be said with certainty that even the underground burrows were those of the shrew. Further, I have found underground nests used by *Microtus*, notwithstanding the emphasis which Rhoads (1903, p. 100) places on the statement that the nests of this species are built "*at the surface*." The position of any nests that might be found could not then be used as a safe criterion. Some of the burrows had heaps of shells near them, which could serve as the criterion if it were known that *Microtus* never used snails for food. To determine this point, two meadow voles were confined in iron cages in the laboratory. Each was given a vessel of water, and equal care was taken to keep each cage clean and dry. One *Microtus* was given corn, wheat,

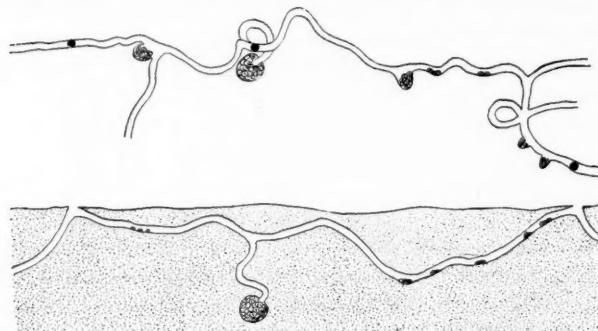


FIG. 2.—Diagram of a typical burrow of *Blarina brevicauda*, showing distribution of snail shells, and an underground storage chamber with spiral descent. The upper figure is a horizontal projection; the lower an ideal vertical section. The black circles in the upper diagram are points where the burrow descended abruptly into the ground.

crackers, bread crumbs, etc., the other only a few live snails. At the end of 30 hours the latter *Microtus* was dead, but the former lived for several days, when it was removed from the cage. Fearing that such an early death might have been due to injuries received in capture, I confined two other voles in similar cages. Each was given only water and snails. One died in 48 hours, the other in 56. Later eight voles were captured and kept in confinement for a week to insure that they had not suffered injury while being captured. They were all in excellent condition at the end of this time. They were then confined in pairs successively, one of each pair being given its common food (grains, crackers, etc.), the other

only water and snails. In each case the one confined with snails died in less than 48 hours, the other remained in good condition. From these experiments I have concluded that all burrows with snail shells in or beside them were at one time used by the shrew. Taking this as the only criterion at first, I found other features later which distinguished the burrows of the two animals.

The burrows used by *Blarina* were usually 25 to 30 mm. in diameter. Those at the surface were exactly like those of *Microtus*, running in zigzag fashion under weeds and grasses, often pushing the latter aside, sometimes crushing them down, crossing and re-

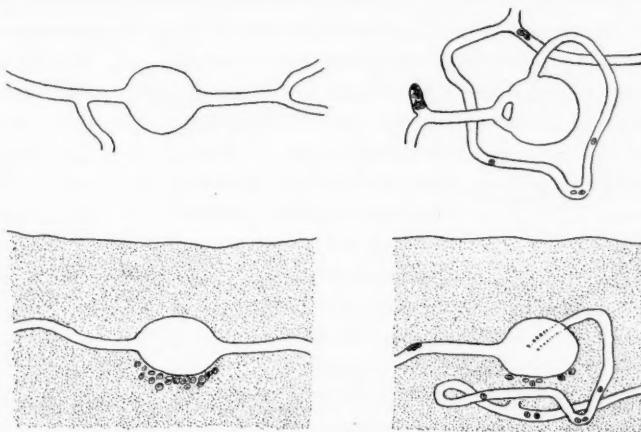


FIG. 3.—Diagrams of two nests of *Blarina brevicauda* and the burrows near them, showing distribution of snail shells. The upper figure in each case is a horizontal view; the lower an ideal vertical section.

crossing to form a complex network which in several cases was easily traced for 30 meters. When the burrows entered the ground, they did so at a steep angle, as Kennicott (1857, p. 94) has described. After descending 15 or 20 cm. they became more nearly horizontal, and passed along between 3 or 4 and 40 cm. below the surface. Branches were frequently sent off, at almost any angle. There was no ridge of earth above the burrow, even when the latter came near the surface, though Stone and Cram (1902, p. 181) mention such ridges. A typical burrow is represented in horizontal view and in ideal section in Fig. 2. Usually the burrows returned to

the surface, rising as abruptly at one end as they had descended at the other. The two openings of a single burrow were never found closer together than a meter, and they were occasionally four meters apart. This fact gives another means of distinguishing the burrows of *Blarina* from those of *Microtus*. As far as I have observed, the openings of an individual underground burrow of *Microtus* were never as far apart as a meter, usually not more than 35 or 40 cm. *Microtus* burrows, moreover, were not found to extend as deep into the soil as those of *Blarina*.

Nests and the Burrows Near Them.—Nests are found along the course of the burrows. In digging out the burrows some sixteen nests were unearthed. Some of these were along ditch banks where the groundwater level was lower than elsewhere. All the others were in small elevations such as mounds where celery had been buried or hills thrown up by roots of fallen trees. The nests were



FIG. 4.—Excrement of *Blarina brevicauda*. Natural size.

found at depths of 15 to 40 cm. They were 12 to 15 cm. in diameter, and slightly depressed from the spherical form. They were usually made of grass, sedge, and leaves of nettle, goldenrod or ash, arranged in the form

of a hollow ball, the shell of which was 1 to 3 cm. thick. One was composed entirely of hair which microscopic examination showed to be that of the meadow vole. When plant materials were used, the plants furnishing them were invariably found immediately adjoining the nest. If grass was near the nest, it was used almost to the exclusion of other leaves. Coarse materials were used without being shredded or torn into smaller pieces. This constitutes an easy distinction between the nests of *Blarina* and such nests of *Microtus* as are constructed of anything larger than grass. In all the nests of *Microtus* which I observed, coarse materials were torn apart; sedge leaves 6 to 8 mm. wide were shredded into three or four strips, and corn blades and leaves of trees were torn into irregular pieces of any size less than about 2 cm. When the same kinds of material were used in *Blarina* nests they were in no way subdivided.

Very rarely, in the vicinity of nests, the excrement of *Blarina* was found. In the laboratory, the excrement was piled up in the corners of the cage, but the only deposits found in the field occurred

singly. The excrement was greenish black when fresh, slightly brownish when dry. It was voided in spindle-shaped portions 25 to 30 mm. long, coiled in various ways, as in Fig. 4. Very different is the excrement of *Microtus*, which is found in black or brown spindles only 5 to 8 mm. long.

Usually two, three, or four burrows radiated from the nest. At one nest, however, no burrows could be found. I had followed an ordinary burrow with a rubber tube until the burrow seemed to come to a blind end; the tube could be pushed no further in any direction. Another burrow running obliquely to this one was then excavated. When I had approached within about 35 cm. of the place where the first burrow had been abandoned, the second burrow also was closed. A third burrow approaching the same spot was next dug open, and it likewise ended blindly. A spade was set in at the point toward which the three burrows converged, and at the first spadeful a nest was turned out. The partly eaten body of a meadow vole near by showed that the nest was then being used, and was not a relic of the preceding year. Careful search all round the nest failed to reveal a burrow leading to it. The soft, loose soil was then carefully dug up to a distance of 40 cm. around the nest and 20 cm. below it and examined as it was thrown out to discover the shrew. None was found, so the soil was thrown back and stamped down. At my next visit a burrow opened to the surface directly over the former location of the nest, showing where the shrew had escaped. It had evidently been present when I dug up the nest, but had escaped my spade. In this case I have concluded that the shrew was obliged to force its way through the mass of loose soil for a distance of about 40 cm. every time it entered or left the nest.

At one nest, in addition to three horizontal burrows radiating from it, a fourth was traced obliquely downward from the bottom of the nest, at an angle of about 40° with the horizontal. At a distance of about 60 cm. from the nest it terminated blindly.

At all but one of the sixteen nests unearthed, snail shells were found stored beneath and at the sides of the nest. All the shells at the nests were empty at the time of excavation, between Apr. 10 and June 10. Their number varied from two or three dozen to 166. Empty shells were also scattered at irregular intervals along

the burrows. Sometimes they were thrust into the soil at the sides of the burrow in groups of 2 to 10. At other places short branches led either downward or laterally from the main burrows, and then expanded into chambers filled with shells, mingled with loose soil. Such chambers contained in some cases as many as 80 shells. Generally, all the shells were empty, but one such chamber contained 69 shells, of which 54 were still occupied the last week in April. In several instances when such a chamber was located beneath the main burrow, the branch burrow leading to it was spiral in form, like a winding staircase. One of these is illustrated in Fig. 2. In two instances empty shells, broken exactly like those found elsewhere, were found inside nests which, from their composition of shredded material and position at the surface of the ground, must have been *Microtus* nests.

Method of Burrowing.—The method of burrowing was observed and experimented on in the laboratory, where a shrew captured by hand was kept for some time. When it was first confined, loose black soil was placed in the cage to a depth of about 10 cm. Into this soft soil the shrew at once thrust its nose, and by violent backward and outward strokes of its forefeet, forced its way through the soil like a wedge. No difficulty was experienced in burrowing 20 or 30 cm. in a minute. The movements underground were evidenced by the movement of the soil at the surface; but no ridge was formed above the burrow. When clods were encountered, they were readily moved, even if fifteen or twenty times as large as the shrew and proportionately much heavier.

During the first night a rather elaborate system of burrows opening to the surface at seven or eight points was worked out. The aggregate length of burrow was not known, as I did not dig out the soil, but it included the whole cage which measured 35 by 48 cm.

Some time later the shrew was put into another cage in which sandy soil had been placed. The same method of procedure was followed in attempting to make burrows, but small headway was made. I watched the shrew for half an hour, during which time it had not succeeded in getting under the surface. The next morning a burrow 15 cm. long open at both ends was found. At the end of a week there was an aggregate of 55 cm. of burrow

with three openings. An extension of 40 cm. had been made from one of the former openings. This sandy soil had not been packed. Hence the difficulty in burrowing in it must have been due to its weight, not to its hardness. In neither the black nor sandy soil did the shrew loosen the soil with its teeth as Kennicott (1857, p. 94) has conjectured. Neither then nor at any other time during the confinement of the shrew did I observe any marked surface runs which the animal was in the habit of following. Instead, it ran about anywhere in the cage.

FOOD.

Dietary of *Blarina*.—Two articles of food of *Blarina* have been so far mentioned, namely, snails and voles. A fair idea of the extent to which snails are used as food may be gathered from the data presented in Table II. On Feb. 27, there were at the particular series of burrows represented in this table 146 occupied shells. On Mar. 1, one of the two shrews which were found in possession of the burrows was captured, so that the succeeding work was that of one shrew. By Apr. 7, all but 16 of these snails, that is, 130 in all, had been removed underground. When the final excavation of the burrows was made at the end of April, all these shells were empty. One shrew must, therefore, have eaten 130 snails between Mar. 1 and the last of April.

The only quantitative evidence obtained in the field in regard to the vole diet was found at the nest mentioned above as having been made exclusively of the hair of this animal. Beside this nest, thrust into the loose peat, were the bodies of two freshly killed meadow voles and that of a third half eaten. In addition to these there were several handfuls of hair in which were mixed legs and tails enough for about twenty voles. I could not know how long it had taken to accumulate this mass. The hair was still moist, but was packed so close that moisture would be retained a long time even in the dry soil in which the nest was located.

To determine more accurately the quantity of mice and other foods eaten by the shrew, experiments were made in the laboratory. A shrew was kept in confinement for over five weeks, in a wire

covered cage in which earth was placed to a depth of about 10 cm. When practicable, live food was furnished. Among the various foods tried were meadow voles and house mice (*Mus musculus*), May beetles (*Lachnostenra*) and their grubs, moth larvae, other insects and pupae, earthworms, snails, sowbugs, carrots, crackers, roots of grasses and other plants. None of the last three articles were ever touched as food. If any article proved especially acceptable to the shrew, that food was furnished exclusively for several days, and the quantity consumed was noted. From these figures the average per day was computed. The result in each of the foods thus tested is given in Table III.

TABLE III. Showing the quantities of various foods consumed by an individual of *Blarina brevicauda* when a single article of food was furnished.

Article of food.	Number consumed.	Number of days on which this food was exclusively furnished.	Average diet per day.
Meadow voles	4	6	3
House mice	3	3	1
May beetles (adult)	77	5	15
May beetles (larvae)	26 *	2	13
Earthworms (4 cm. when contracted)	142	4	35

Other articles of food were furnished at other times, and some proved favorites; but owing to the difficulty in securing the food no quantitative data were secured. Other insects, such as various ground beetles, giant water bugs (*Benacus*), and *Hydrophilus triangularis*, were furnished. All were eaten, but the ground beetles were the favorite. Other larvae of insects besides *Lachnostenra* were readily taken, even the "woolly bear" of *Pyrrharctia isabella*. Sowbugs were eagerly devoured. When live food was not to be had, beef was furnished, and was eaten readily. I made only two stomach examinations. One stomach contained an insect larva mutilated beyond recognition; the other the remains of a meadow vole, recognizable by the hairs swallowed with the flesh. Vegetable foods were invariably rejected, though Professor Reighard has captured the shrew in traps baited with nut meats scented with

* Proved insufficient; all were consumed by 11 a. m. on second day.

anise oil, and the specimens taken still had fragments of the nut meats in their teeth.

Method of Capturing Food.—On several occasions I witnessed the capture of prey. In the case of the voles and the mice, the attack was essentially the same as described by Merriam (1886, pp. 166-168) and Morden (1883, p. 283). The house mouse, being very agile, was not taken in the open, but only when it entered the shrew's burrows. I observed this twice. The clumsy vole, on the other hand, was pursued above ground, cornered in the cage, and caught. In each case the shrew seized the animal's ear in its teeth. After the shrew had been dragged around the cage until its victim was almost exhausted, it quickly loosed its hold on the ear, seized the head in the parietal region, and pierced the skull with its teeth. In two cases the prey was dragged part way into a burrow after it had been killed. In the third case it was eaten at once at the surface. The brain and cranium were eaten first, then the neck and shoulders. The skin was closely cleaned and rolled back till the tail was reached. The snout, legs, skin, and tail were left.

Some difficulty was experienced in making observations on the eating of snails. When beef or mice were furnished, snails were not touched. Finally, when all other foods were excluded, snails put in the cage of a morning were devoured before the following morning, though they remained untouched during the day. Learning by this means that the shrew would eat snails at that time of year (early in June), I starved it for a day, then in order to keep it at the surface put it into a cage with sandy soil, and gave it a few snails. The snails were large and their shells were hard. The shrew put its lower jaw into the aperture in an attempt to reach the snail. Once its forefoot was thrust in. Failing to get the snail in this way, it set its teeth across the outer turn of the shell and tried to break it. This it failed to do in my presence, but later the same shells were found broken. It seems from these observations that in the case of large shells, breaking is a last resort. A group of empty shells taken from one of the underground chambers in the series of burrows in which this same captive shrew was taken is shown in Fig. 5. The group on the left contains all the unbroken shells. Those on the right were broken,

being mostly small and immature shells of the same species as those on the left. These small shells were of course much more fragile than the mature ones.

From the way in which the attempt to get the snails was begun, it appears that when the shells are not broken the snails are dragged out through the aperture. I did not see this done. To determine whether it could be successfully accomplished, I seized an extended snail with a heavy forceps and pulled upon it strongly. With a steady pull the attachments to the shell slowly yielded and the snail was removed almost entire.

PSYCHOLOGY.

I have described reels which were set at several of the burrows to determine whether the animal that was moving the snails occupied the burrows. The same reels were used to determine how the occupied shells were distinguished from the empty ones. The possible means that suggested themselves were the weight of the snail, and the senses of touch, sight, and smell.

Muscular Sense.—To learn whether weight was the criterion, an empty shell was stuffed with sandy soil till it was about as heavy as an occupied one. This, with an empty shell and an occupied one, was placed near one of the burrows. Each shell was tied to a reel, and all were placed at equally accessible points. The occupied shell was drawn into the burrow at the time of the first decided rise of temperature, while the other two were left indefinitely. The experiment was repeated, but the occupied shell was so placed that the shrew would have to go round the empty and stuffed shells and under the reel in order to get it. The occupied shell was again removed and the other two left. The experiment was twice repeated at another burrow, with the same results. Evidently weight of shell is not the determining feature. It seemed possible that the center of gravity might not be at the same point in a stuffed shell as in an occupied one, and that the shrew could detect this difference. Therefore the position of the center of gravity in a stuffed and an occupied shell was determined by balancing on a knife edge and by suspension; it was found to be the same in the two shells.

Tactile Sense.—It might be supposed that the shrew would reach into a shell with its feet and feel whether the snail was there. I found later that the tactile sense was acute. When the shrew was running at full speed in its cage and came upon an obstacle, it invariably stopped short before touching it except with its vibrissae. The most common obstacle was its water dish, which was frequently moved about to different places in the cage. I am not certain that I ever observed the shrew run against the water dish even immediately after it had been moved. I have seen the shrew run past masses of such favorite food as earthworms without

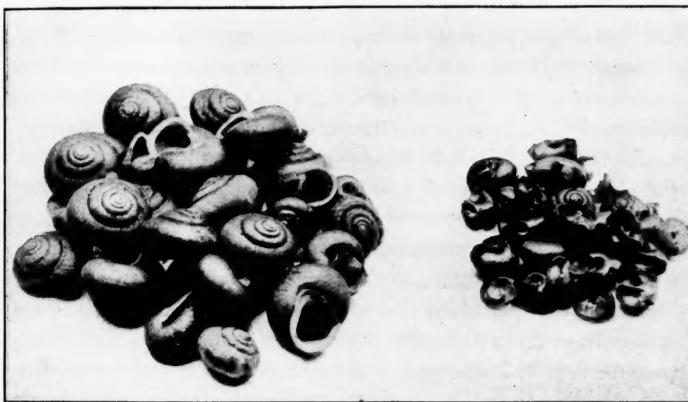


FIG. 5.—The empty shells taken from a single underground storage chamber of *Blarina brevicauda*. The shells on the left were entire; those on the right broken, being mostly immature shells of the same species as those on the left.

noticing them, but when a worm in its wriggling touched the tactile hairs, the shrew turned at once and seized it. To learn whether the tactile sense was used to determine the presence of a snail in its shell, I stuffed the apertures of several occupied shells with soil firmly, so that the snails were out of sight and reach. The external appearance of one of these shells was to a human observer precisely like that of a stuffed one, unless it was held up to the light. Then the central turns of the unoccupied shell into which it was impossible to force the soil appeared lighter than in the shells containing snails. The shells with apertures closed with dirt were placed,

along with stuffed and empty shells, at several burrows. The occupied shells were again removed, to the exclusion of the others.

Sight.—*Blarina* has not been accredited with acute vision, the principal function of its eyes being, as Merriam (1886, p. 165) has supposed, to distinguish light from shadow. To determine this point at first hand, various tests were made on the shrew in the laboratory. Objects varying in size from a lead pencil to a book were waved before the shrew, first at a distance of a foot or more. No notice was taken of them. The distance was gradually shortened until the objects almost touched the shrew's vibrissae, but still the animal was not disturbed. Once when a cigar box was thrust violently toward the shrew, the latter shrank back and immediately turned to face the object. Thinking that the response might have been due to air currents, I moved various objects, as cards, boxes, or books, toward or past the shrew in an oblique position so as to produce currents. The shrew invariably noticed these although its head was sometimes turned away from the object. I then blew lightly upon the animal and it turned toward me and chattered vehemently. I have concluded that, in the above case where notice was taken of the cigar box, the response was due to air currents, and that the box had not been seen.

The above experiments were all performed with the cage between the moving objects and the window. When similar movements were made on the opposite side of the cage so as to throw a shadow over the shrew, the animal was at once disturbed. If a large object, as a book, were used to cast the shadow, the shrew frequently hurried into one of its burrows. Sight, then, can hardly serve to distinguish occupied from empty or stuffed snail shells in cases where a human observer could not discern a difference. The remaining possible means of distinguishing them is by their odor.

Smell.—When mice or beef were placed in the cage the shrew almost invariably came out of its burrows in a short time. It rarely did so when the lid was merely raised and lowered, or when other objects, as the water dish, were put in. In the case of the mouse, the response may have been due either to the trembling of the soil as the mouse ran about, or to the odor of the mouse; but with the beef, the disturbance of the ground was eliminated. When the shrew was above ground, it was always going about

with its nose slightly elevated and its nostrils dilating and contracting rapidly in unison with movements of the sides of the body, as if sniffing the air. It is further noted (Table I) that only 7 of the 25 snails killed in formalin were ever moved from their places at the burrows in the field. I have concluded from all these observations that the distinction between empty and occupied shells is due chiefly to the odor of the snail. Possibly weight is another factor, for although the experiments showed that weight was not effective apart from odor, no experiments were performed with odor apart from weight.

Hearing.—It has been pointed out by both Merriam (1886, p. 165) and Kennicott (1857, p. 95) that the hearing of the shrew is acute. This was not at once apparent from the shrew that had been for some time in confinement. It was oblivious to sounds that were often repeated. It took no notice of footsteps, and conversation did not disturb it. Even the slamming of the door did not at the last appear to be perceived, but slight sounds that I produced for the first time made the shrew start. Plucking a taut string within a foot of the shrew produced this result. A shrill whistle caused it to run into the corner of its cage, though I was careful not to blow upon it. It started violently when a strip of metal was drawn across the lip of a tin can near the cage. Each of these noises when repeated a number of times at various intervals ceased to produce any effect, even when several days had elapsed since last producing them. The flutter of wings of a pigeon kept in the same vivarium, on the other hand, always sent the shrew scurrying into its burrows. I observed this more than twenty times, at intervals throughout the five weeks of the shrew's captivity, and the last flutter produced as much disturbance as the first. This particular sound must have been heard hundreds of times during that period, yet even at the last could not be heard with equanimity by the shrew.

Effect of Light and Heat.—Sufficient evidence has been offered that most of the shrew's work on snails is done at night. Eight of eleven voles and mice put into the cage of the shrew were killed at night. Most of the food which was small enough was dragged into the burrows to be eaten. In my field work I twice saw a shrew come momentarily to the surface, once in March and once

in April. Both days were rather cool, though the sun was shining brightly. Still more conclusive, at least in regard to heat, was the behavior of the shrew when brought out to be photographed in a dish lined with white paper. The animal was exposed to direct sunlight when the temperature was about 30° C. It tried at every point to get under the paper lining of the dish, while its breathing rapidly increased. After some 8 minutes of exposure it was evidently overcome by heat, and after dancing wildly about a short time on all fours, lay motionless. Long continued bathing with cold water was necessary to restore it. It is evident that times of daylight and even ordinary summer heat are not selected by the shrew for its greatest activity. On the other hand, even if there were no direct evidence of daylight activity, the capture of shrews by hawks (Fisher, 1893) shows that the animals occasionally come out upon the surface by day.

SUMMARY OF PRINCIPAL RESULTS.

1. *Blarina brevicauda* preys upon various snails of the genus *Polygyra*, at least in winter.
2. These snails are hoarded, and are in general moved to the surface of the ground as the temperature falls and into the burrows as it rises.
3. Empty shells which are brought to the surface are not moved back into the burrows. The basis of distinction between empty and occupied shells is the odor of the snail, or possibly the odor combined with the weight.
4. Empty shells not left at the surface are stored about the nests, along the burrows, or in special chambers.
5. Other principal foods are voles, mice, insects, and earthworms. Vegetable foods, except nuts, are not employed.
6. The burrows of *Blarina brevicauda* are similar to those of *Microtus pennsylvanicus*, but may be distinguished by the following features:
 - a. The runs of *Blarina*, when underground, open to the surface at points more than 1 meter apart; those of *Microtus* have openings less than 1 meter apart. Burrows of *Blarina* often extend as deep as 40 cm. into the soil; those of *Microtus* rarely more than 15 cm.

b. The nests of *Blarina* are always underground; those of *Microtus* are more usually at the surface.

c. *Blarina* uses all its nesting materials unaltered; *Microtus* shreds or tears coarse material.

d. The excrement of *Blarina* is greenish black, coiled spindle-shaped, about 25 mm. long; that of *Microtus* is black or brown, spindle-shaped, 5 to 8 mm. long.

7. The smell, hearing, and tactile sense of *Blarina* are acute; its sight serves merely to distinguish light from shadow.

DISCUSSION.

The short-tailed shrew is easily recognized. It differs from other shrews by its large size, having a total length of 120-124 mm., by its short tail (23 mm.), and relatively small feet (hind foot, 15 mm.). From the common mole and Brewer's mole, it is distinguished by its smaller size, and by the absence of digging forefeet; from the starnosed mole it is further separable by the absence of tentacles around the snout.

In the field, the work of *Blarina* is readily distinguishable from that of either the common or starnosed mole by the smaller burrows, and the absence of humps of earth which are so characteristically heaped up by both moles. A further distinction is the ridge of earth over the burrows of the moles, especially the common mole. *Blarina* does not make such a ridge, at least in soft ground.

It has been noted that the runs used by *Blarina* at the surface of the ground are precisely like those of *Microtus* but that the burrows as a whole differ in several respects. The most interesting of these differences concerns the material of which the nests are composed. Shredding or tearing it into pieces would perhaps make the nest more comfortable and the shrew is fully capable of thus altering its material. But the shrew is carnivorous and *Microtus* is a rodent. To the latter, with its gnawing incisors, accustomed to dividing and tearing roots of grasses and the bark of trees, the shredding of nesting material is a natural process.

The collecting of empty shells around the nest of the shrew seems significant in relation to the origin of the nesting habit. One nest which I have described was made entirely of the hair

of the vole, rejected parts of its food. *Microtus* nests are commonly made of the husks, leaves, and silk of the corn, or of the chaff and leaves of the wheat which it devours. It is easy to conceive that in this way the nesting habit of the shrews also originated. If this be true, the use of grass, leaves, and sedge, now so common among the shrews, must be a secondary modification, since these articles are not rejected food materials.

The fact that in the laboratory the shrew did not make any defined runs at the surface, suggests that it may not make any in the field. If this is true, the runs which it occupies were probably made by *Microtus*. They may have been entered in pursuit of game, and when the original owners were captured, their burrows were appropriated. The finding of broken snail shells in *Microtus* nests seems to support this view, since *Microtus* does not eat snails. The shells must have been carried thither on a foraging expedition, and devoured in the nest of the vole. To what extent the runs used by *Blarina* have been appropriated by it has not been determined.

Many of the shells found around the nests of *Blarina*, in underground chambers, and in the burrows, were shown by the numbers painted upon them to be those which were previously heaped at the surface. The snails, therefore, were being hoarded, and used gradually. Bachman (1837, p. 370) mentions that beetles are hoarded by shrews of the genus *Sorex*, and Merriam (1886, p. 169) thinks it probable that *Blarina* stores food. Dahl (1891) has found masses of earthworms, having their anterior segments injured, in the burrows of the European mole; but Adams (1903, p. 14) thinks they merely fell in and could not get out,—he does not explain the injury of the anterior segments. There is no mention of hoarding among shrews on as large a scale as this of the snails seems to be. It has been noted that the snails were carried out on top of the ground in considerable numbers when the temperature fell markedly, and were taken back in equally large numbers when there was a marked rise in temperature. The snails seem to be kept in the coldest place available. In cold weather this is above ground; in warm weather, in the burrows. Though the temperature in February and March never rose high enough to render the snails active, yet some of the snails at the burrows referred to in Table II were still at the surface

early in April when it was warm enough for them to crawl. This may have been due to the fact that my first shrew was captured at this set of burrows, so that only one shrew was left to devour the snails originally intended for two. Bodies of *Microtus* were hoarded but were not transferred to the surface. This again indicates that the cold storage serves to keep the snails immobile rather than to prevent decomposition.

Too little has heretofore been known of the short-tailed shrew to make an estimate of its economic importance practicable. Stomach examinations are almost wanting, my own work including but two. However, from data concerning the quantities of food in laboratory and field, I have attempted an estimate of the economic importance of *Blarina*.

Three principal elements determine the economic value of a species, namely its range, its abundance, and the character and quantity of its food. Of the range of *Blarina*, Rhoads says (1903, p. 192): "Atlantic Ocean to Nebraska and Manitoba; Quebec to Virginia." This is practically the northeastern quarter of the United States. Of its abundance, the same author says (p. 193): "This species stands preeminent above all others of our mammals in its combined abundance and universality of distribution in all conceivable situations. Not a place have I trapped over in the two states but what it was among the first species to be caught. It is found in our deepest, coldest mountain ravines, on the stormy, barren mountain top, in the banks and valleys of low tidewater streams and maritime marshes, and delights in roving from the cool sphagnum bogs of the N. J. cedar swamps where the temperature may be below 60° to the hot sand barrens of the adjoining fields with a mid-day heat of 110°. Forest and plain, sand and clay, barren or fruitful field, back woods or door yard, heat and cold, wet and dry, day and night, have common charms for this cosmopolite." It is difficult to conceive of the shrew in some of these situations after having observed its almost futile attempts to burrow in heavy, sandy soil that was not even compacted. Yet numerous records attest its presence in these situations.

Montgomery (1899, p. 572) has used the number of skulls of different mammals found in the pellets of owls to determine the relative abundance of the animals. Shrews necessarily came far

down the list, because few were captured; and he found that *Blarina parva* is more abundant than *B. brevicauda*. It seems to me that the small number captured is due to the fact that they are underground most of the time, rather than to their rarity. From my own observations, assuming that a pair was present at each nest that was being used, as I found to be the case in two instances, there were at least two pairs to the acre over the region studied. This number should be easily maintained for, according to Rhoads (1903, p. 195), they produce four to six young at a litter, and breed the year round.

The quantity of food eaten in a month has been estimated as follows: From Table III was computed the quantity of each item which would have been consumed in a month had that article alone been furnished. For example, one month's rations of voles alone would be 20; of house mice, 30; of adult May beetles, 450; and so on. It has already been stated that 130 snails were eaten by one shrew between Mar. 1 and Apr. 31. However, since the moving of the snails by the shrew had practically ceased by Apr. 7, it seems probable that the snails were eaten in a little over one month. Moreover such other foods as insects, earthworms, and voles were available at the same time, so that the snail diet was not the total. It seems reasonable to assume that 120 snails alone would make one month's rations, since that is more nearly the equivalent of 20 voles.

The distribution of the dietary among the different articles is largely a matter of judgment, and in Table IV the quantities are based on the relative abundance of the various items in the swamp region studied. For example, voles were abundant, and have been allowed to constitute 40% of the diet. Earthworms, on the other hand, were comparatively rare in the peat of the swamp, and have been allowed but 5%. The table of course represents only a sort of average for the year. Snails are evidently eaten in much greater numbers during several months of the winter, when the insect diet is necessarily limited. The snail diet is probably less in upland situations, though Charles A. Shull, of Kentucky University, tells me he has found the characteristic heaps of snail shells, all *Polygyra thyroides*, about the openings of small burrows in high land near Lexington, Ky. This was probably the work

of *Blarina*. In other situations than the peaty swamp, the earth-worm diet is probably greater than I have estimated. In proportion as other foods not here included are employed, the quantities in the table will be diminished.

TABLE IV. Showing estimated quantities of various staple foods devoured by a single *Blarina brevicauda* in one month.

Article of Food.	Estimated number eaten.	Per cent. of total rations.
Meadow voles (or equivalent in mice)	8	40
Adult insects (of the size of <i>Lachnostenra</i>)	90	20
Insect larvae (of the size of <i>Lachnostenra</i>)	78	20
Earthworms (4 cm. long in contracted condition)	53	5
Snails	18	15

Estimating the number of shrews as I have done at four per acre, it appears that the number of meadow voles devoured by them on a farm of 100 acres in a year is $100 \times 4 \times 12 \times 8 = 38400$. Since this number can scarcely be supplied, the capacity of the shrews for keeping the voles in check is not strained. Where this quantity of voles can not be found, either other foods must be eaten in equivalent amounts, or the shrew is capable of subsisting on shorter rations, or the estimated four shrews per acre can not exist. Farmers should take note of the economic value of *Blarina*. In their zeal to rid their premises of noxious animals, they sometimes kill indiscriminately anything that looks like a mouse. One of these animals evidently kills many more voles in a year than the farmer himself. The shrew even compares favorably, from the economic standpoint, with the common owls. Montgomery (1899) examined the pellets of four long-eared owls for a period of two months, and found that these birds had devoured 347 small mammals, mostly *Microtus*. This is an average of 43 per month for each owl. *Blarina* devours 20 voles per month, or an equivalent in insects, most of which are even more destructive than the voles.

With abundance of food, it might be expected that the race of short-tailed shrews would become very numerous. But other forces are at work maintaining the balance of nature. The investigations of Fisher (1893) show that six species of hawk and six species of owl capture the short-tailed shrew. Two other species

of owl capture shrews but the species of shrew is not stated. Montgomery (1899) found the skulls of shrews in the pellets of the long-eared and the short-eared owl. The number of shrews taken, however, is relatively small. For example, Fisher (1893, p. 53) found in 562 stomachs of the red-tailed hawk 45 specimens of shrews. Of these one third were short-tailed shrews, taken in 10 individual stomachs. In 39 stomachs of the barn owl (p. 139) 5 specimens of shrews were found, among which was *Blarina*. Montgomery (1899, p. 566-567) found that out of 347 skulls of mammals taken from the pellets of the long-eared owl, only one belonged to *Blarina*. These figures show that the item of shrews does not count very heavily against the hawks and owls in estimating the economic value of these birds.

The subject of bird enemies of the shrew recalls the disturbance produced in the laboratory by the fluttering of the pigeon's wings. The sound was probably recognized as a familiar one by the shrew. This accounts for the fact that the animal never became oblivious to this particular sound.

Surface (1906, pp. 155, 160, 189, 197) has found shrews in the stomachs of four species of snake, though in small numbers. In at least one case he was able to identify the specimen as *Blarina*. Rhoads (1903) and Stone and Cram (1902) state that small mammals are captured by foxes, minks, weasels, and skunks. In several instances they mention shrews among the number, but in no case is specific mention made of *Blarina brevicauda*. Dicker-
son (1907, p. 356) records that three specimens of *Blarina brevicauda* were found dead in the fallen nest of a red squirrel. She believed them to have been killed and stored there by the white-footed mouse. This mouse is well known to utilize deserted nests, among others that of the red squirrel, but whether it kills shrews is doubtful. It appears to me more probable that the shrews had been killed by larger beasts of prey and rejected, possibly on account of their odor (Rhoads, 1903, p. 193; Stone and Cram, 1902, p. 182), and had then been picked up by the whitefooted mouse. This mouse is said by Stone and Cram (1902, p. 132) to glean after other hunters.

From bird enemies the shrew can escape to its burrows. From those enemies that can pursue it in its burrows, some other means of

escape must be employed; perhaps it pushes out into the loose soil. The instance of the obliquely descending burrow at one nest suggests the "bolt run" by which the European mole is said to escape when its fortress is attacked (Adams, 1903, p. 13). This burrow, however, was probably not a back door escape, since it ended blindly and the shrew did not enter it at this time of attack.

The short-tailed shrew is so well protected from its enemies that no animals appear to depend upon it for food. It is abundant and widely distributed. In security it devours such quantities of voles and insects that its economic importance is considerable; and since, unlike the other common shrew, *Sorex personatus*, it is almost exclusively carnivorous, there is little to detract from its economic value.

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NOTES AND LITERATURE

GENERAL BIOLOGY

The Philosophical Problem of Life.—Dr. Verworn, Professor of Physiology at Göttingen, has recently published a lecture upon the investigation of life, delivered before the society of political science at Berlin.¹ At the outset he states that the search for a cause in biology is unfruitful and unscientific. “There is no process in the world which is determined by a single cause. Every process is always dependent upon a number of other processes and it is unjustifiably arbitrary to select one of these and to account it the first cause.... A scientific investigator can only establish the several conditions which are necessary for the occurrence of a process. If these are known, the process is accounted for,—explained. The process is nothing more than the expression of the sum of the concomitant conditions. The conception of cause becomes therefore superfluous and worthless.”

Accordingly one must regard as superficial such affirmations as that an insect is colored green because it is thereby protected, or that a mammalian embryo has gill clefts because its ancestors did.

From the study of the conditions of life Professor Verworn concludes that,—“To produce life artificially we must know completely *all* the elements of the living substance. We must know the relative amounts. We must understand their arrangement in the cell body. If we could construct such a system, fulfilling all the conditions of life, the artificial cell would at once live. It would certainly be extremely interesting to see how the artificial organism would live, reproduce, and transmit its qualities—but the prospect of producing life is a complete Utopia. We have not learned to approach the complex conditions involved in a living organism.... The chemical fabric of a cell should first be so understood that it could be imagined as a great machine shop, in which the mechanism of life could be observed by wandering among the atoms as among wheels and cylinders.”

Consciousness also is held to be a product of these conditions. If, according to DuBois-Reymond, we could bring together at once and in their proper relations all the atoms of which Cæsar was composed

¹ Verworn, M. *Die Erforschung des Lebens.* Gustav Fischer, Jena, 1907. 45 pp. 1 Mk. 80 Pf.

when he crossed the Rubicon, we should have reconstructed Cæsar, body and soul. The artificial Cæsar would have the same sensations, aspirations, and ideas as his predecessor at the Rubicon. Both consciousness and life, therefore, are the expression of definite *conditions* to determine which is the object of scientific investigation.

Professor Verworn here ascribes as a cause of consciousness an unknown arrangement of atoms. A more conservative opinion has been expressed by an American biologist, as follows,¹— “The work of physiologists has been so devoted to the physical and chemical phenomena of life that the conviction is widespread that all vital phenomena are capable of a physical explanation. . . . Let us give up the ineffectual struggle to discover the essential nature of consciousness until we can renew it with much larger resources of knowledge.”

In regarding the construction of a living cell as a complete Utopia, Professor Verworn differs from Professors Le Dantec and Cresson. The former writes,²— “Our knowledge of colloids is still so recent and rudimentary, that we ought not to expect to see the making of a cell accomplished soon; but it will come some day by careful analysis, permitting a rational synthesis. . . . The scientific world today is so prepared for the discovery that the premature announcement of spontaneous generation in gelatine submitted to the action of radium surprised no one. . . . It is not necessary for an enlightened mind to see protoplasm made to be convinced of the absence of any essential difference,—any real discontinuity, between living and dead matter.”

Professor Cresson,³ after quoting Büchner that “doubtless some day it will be possible to form living protoplasm artificially,” adds,— “Such a hope is at least somewhat reasonable and probable.” When, however, it is considered that nowhere in nature are such conditions known to be realized at present, and that the conditions in the past when life arose are equally unknown, one is inclined to accept Professor Verworn’s characterization,— a complete Utopia.

It is unnecessary to refer further to Dr. Le Dantec’s volume, which was published some months ago in English, and has been frequently reviewed. Dr. Cresson’s more recent volume is a simple introduction to naturalistic philosophy. The author describes the development

¹ Minot, C. S. The problem of consciousness in its biological aspects. *Science*, N. S. vol. 16, 1902. pp. 1-12.

² Le Dantec, Félix. *Éléments de philosophie biologique*. Félix Alcan, Paris, 1907. 297 pp. 3 fr. 50.

³ Cresson, André. *Les bases de la philosophie naturaliste*. Félix Alcan, Paris, 1907. 179 pp. 2 fr. 50.

of natural science and its conflict with the "old geocentric and anthropocentric philosophy which seduced and satisfied our ancestors.... Science has descended upon this philosophy like a tempest and nothing is left. The earth is not the center of creation. Man is not an exception in the universe. The adaptation between living things and their environment is explained by evolutionary principles without supposing an intelligent creator." In the preface, philosophy is said to be a matter of temperament. "For some, naturalism is the final word of true metaphysics; for others, it is devoid of all truth." In this way, perhaps, the author acknowledges, that there are many who see in evolutionary principles the manifestation of an intelligent creator; and who find in man, though one animal among many, much that is exceptional. It is stated by Professor Cresson that naturalistic philosophy is not science, though suggested by it. The determination of the conditions of life, as described by Verworn, is science itself.

F. T. L.

The Capitalization of Specific Names.—It is agreed that the name of a genus shall always begin with a capital letter and that the specific name shall usually begin with a small letter. Zoologists are inclined to begin specific names invariably with small letters, but botanists employ capitals for a variety of purposes as shown in the following examples:

Zoological Names.	Botanical Names.
a. <i>Sitta canadensis</i>	<i>Juncus Canadensis</i>
b. <i>Lampetra wilderi</i>	<i>Smilax Walteri</i>
c. <i>Gastropacha ilicifolia</i>	<i>Lythrum Hyssopifolia</i>
d. <i>Bernornis isabellae</i>	<i>Rosa Beatrixis</i>

Whatever reasons exist for beginning these botanical names with capitals apply with equal force to the zoological names; and the advantages of the invariable rule for lower case letters are no greater in zoology than in botany. Moreover, as expressed by the Vienna Congress of botanists,—"The principles and forms of nomenclature should be as similar as possible in botany and in zoology." In the matter of capitalization of specific names, one rule should apply to both. In order to determine upon a uniform practice for the *Naturalist* (in which botanical and zoological names should appear with equal frequency) the editor examined the following codes.

1842. A committee of the British Association, appointed "to consider of the rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis," presented various

"Recommendations for improving the nomenclature in future." Among these is § C. "Specific names should *always* be written with a small initial letter, even when derived from persons or places, and generic names should always be written with a capital."

1865. The British Association code was revised, and although the rule for small letters had been very generally adopted, the section relating to it was omitted. The revised code stated that "It is not a matter of great importance and may be safely left to naturalists to deal with as they see fit."

1881. The Société Zoologique de France stated,—"Every one agrees that the name of the genus should be written first and begin with a capital letter. For the specific names, there is also unanimity if they are common nouns or adjectives,—a small letter is used. Should proper nouns and adjectives be treated in the same way? Some persons adopt and recommend the practice. Your committee considers that the question is of very minor importance. It believes that it conforms to the most generally established usage in recommending the capital, which is not inconvenient, and may in fact, in certain cases, be a useful distinctive mark."

1881. The rules of the International Geological Congress at Boulogne, in regard to the nomenclature of species, merely state that "the rules of Latin orthography are to be followed."

1886. In the code of nomenclature adopted by the American Ornithologists' Union, Canon VIII states that "proper names of species, and of subspecies or 'varieties,' are single words, simple or compound, . . . written with a small initial letter."

1893. The Deutsche Zoologische Gesellschaft adopted a code containing the following note to § 10. "It is very desirable to write not merely all adjective but also all substantive specific names invariably with small letters."

1904. A committee of the International Zoological Congress framed a code containing Art. 13.—"While specific and substantive names derived from names of persons may be written with a capital initial letter, all other specific names are to be written with a small initial letter."

1905. At Vienna the International Botanical Congress adopted the following *recommendation*. Chap. III., Sect. 4. Recommendations. X. "Specific names begin with a small letter except those taken from names of persons (substantives or adjectives) or those which are taken from generic names (substantives or adjectives)."

1907. The nomenclature commission of the Botanical Club of the

American Association for the Advancement of Sciences rejected various fundamental principles of the Vienna code and framed an 'American code'. Part 3, § 1, art. 3 reads,— "If capital letters are to be used for specific names they should be employed only for substantives and for adjectives derived from personal names." This is followed by the curious example *Uromyces Trifolii*, and in another place the specific name *Tulipifera* is capitalized.

The examination of these codes shows that the most radical rule was that of the British Association in 1842, and that this was subsequently cancelled. Nevertheless the progress toward its adoption seems constant. The botanists have ruled against capitals for nouns and adjectives denoting places (example *a* in the list). Since a very large number of botanical names are of this sort, the progress toward decapitalization is considerable. Capitals for personal names are recommended by the botanists, small letters by the German zoologists and American ornithologists, and both forms are sanctioned by the international code of the zoologists. The botanists are alone in recommending capitals for specific names derived from those of genera (example *c*). Under this rule a person unfamiliar with the genera of plants must refer to an authoritative botany to ascertain the capitalization,— thus a zoologist would not expect to find *Datura Stramonium* and *D. Tatula* capitalized. Should a botanist desire to refer to a zoological species, however, a check list need not be consulted regarding the capitalization. Since no single practice can conform with all the codes and yet a uniform rule is obviously desirable, the *Naturalist* will capitalize specific names only at the request of a contributor; the invariable use of small letters is recommended. It is to be noted that the Vienna code allows choice in this matter. Chapter I, Art. 3, states that "the rules of nomenclature should be neither arbitrary nor imposed by authority,— they must be simple and founded on considerations clear and forcible enough for every one to comprehend and be disposed to accept."¹

¹ Since this was written the University of Missouri has issued *The Flora of Columbia Missouri*. The specific names derived from places are capitalized contrary to the Vienna code. The confusing nature of the capitalization is apparent from the following examples,— *Leonurus Cardiaca*, *Apocynum hypericifolium*, *Robinia Pseudacacia*, *Vernonia pseudobaldwinii*. The corrigenda include,— for *Achillea millefolium*, read *A. Millefolium*. *Potentilla Norvegica* of the text is indexed as *P. norvegica*. In Dr. Cockerell's *Bees of Boulder County, Colorado*, also just received, all specific names of plants visited by the bees are written with small letters, e. g. (p. 243) *Linum lewisii*. This is the practice which the *Naturalist* adopts.

The opinions of the botanists who are associate editors of the *Naturalist*, upon the capitalization question are as follows:

a. "I shall be very glad to follow the practice of lower case spelling for specific names in conformity with zoological usage."

b. "I am not very positive in my opinions of right and wrong on the capitalization question. I am going to try to follow the Vienna practice as consistently as possible. The zoological decapitalization has some valid arguments against it. In its favor is the fact that no knowledge is required on the part of those who adopt it, other than that the specific name chosen is to be used. I should suppose that for the *Naturalist* a uniform practice for the different departments of biology would be adopted, and the line of least resistance would be uniform decapitalization. Any proof-reader is then competent to correct all deviations."

c. "I have no decided opinion on the subject. My instinct is to use capitals for adjectives derived from proper nouns, as it somehow does not look right to me to see them spelled with small letters. I have no objection to offer if it seems best to adopt the uniform rule of small letters for specific names."

d. "Botanists should follow the international code. Personally I come near it, that is, I write names derived from persons with capitals, e. g., *Goldoni Lewisi*, and names derived from other proper nouns with small letters, e. g., *Goldoni pennsylvanica*. American scientific men (some of them) seem never satisfied to do things in nomenclature the way the rest of the world does. Really we ought to write *G. Lewisi*, and *G. Pennsylvanica* following the genius of the Latin language."

In order to know whether Latin usage had any bearing upon the question at issue, the last sentence in this quotation was referred to Dr. A. A. Howard, Professor of Latin at Harvard College, who wrote, — "There are no ancient rules whatever for the use of capital letters in Classical Latin. Our earliest manuscripts are written throughout in capitals, and so are all inscriptions. When the minuscule letters were introduced, the capitals were sometimes, but not always, used to begin a sentence or paragraph, apparently only as a sort of embellishment. Proper names are written in small letters down to the time of the introduction of printing. Therefore it is absurd to talk about the genius of the Latin language in this connection. All rules for capitalization are of modern origin, necessitated by the invention of printing. It is customary for each country to follow, in writing Latin, the rules governing the language of the country, though German writers not infrequently begin Latin sentences with small letters."

e. "The question of capitalization of specific names has given me much concern, and I should be very glad were it possible to reach some practice which would be acceptable to *all* zoologists and botanists. At the present moment no less than three rules are in use by botanists. Personally I see no good reason for capitalizing any specific names and my preference is decidedly in favor of following the practice of the zoologists. Some botanists consistently adhere to the rule of *no* capitals and they are right. In adopting this rule, you would make the *Naturalist* the exponent of a uniform practice for all biologists, and would, I feel sure, gain the support of many botanists."

F. T. L.

ANTHROPOLOGY

Handbook of American Indians North of Mexico.¹—The volume at hand is the first of the two parts of a most important and generally useful work, dealing with the North American Indian and prepared under the auspices of the Bureau of American Ethnology. The work is an encyclopedia of the Indian, dealing in alphabetical order, with every phase of his life as well as with his anatomical, physiological, and indirectly also with his mental characteristics. Preparations for this publication have been carried on since 1873, and since 1902 the task has been in the hands of a special editor. The second volume will probably appear in the course of the coming winter.

The work is the result of contributions of forty-six authors, specialists in various branches of anthropology throughout this country. Every article in it has not only been carefully supervised by the able official editor of the book, Mr. Hodge, but has also been sent for reading and suggestions to all the contributors. Moreover, there were held at the Bureau of American Ethnology, under the chairmanship of Professor W. H. Holmes, for many months, regular meetings three times a week, to which all the authors were invited, and where all the more important papers were read and freely discussed. The result, great credit for which is due to Professor Holmes, the Chief of

¹ Hodge, Frederick W., *editor*. *Handbook of American Indians north of Mexico*. Part 1. *Bur. of Amer. Ethn.*, bull. 30, Washington, 1907. 972 pp., with a map and numerous illustrations.

the Bureau of Ethnology, besides to the editor, is a compilation of brief but comprehensive, simply worded and well illustrated, authoritative articles, which represent the substance of our actual knowledge of the Indian. A further perfection and possibly extension of the subject matter will be attended to in future editions.

The work will prove in general a satisfactory reference book on the North American aborigines, and a valuable handbook on the subject in higher schools and colleges. It has, with its other merits, the distinction of being the first work of its nature in existence. The bibliography, though mostly restricted to synonymy, according to the original plans of the work, is nevertheless ample and will facilitate the researches of special students.

Among the authors contributing to this work are Miss Fletcher, Chamberlain, Fewkes, Kroeber, Gatschet, Cyrus, Thomas, Hewett, Boas, Cushing, Colville, Hodge, Hrdlicka, Hough, Dorsey, Mason, McGuire, Mooney, Swanton, Dixon, Culin, Matthews, Hewitt, Grinnell, Henshaw and others.

Among the individual articles may be mentioned Abnaki, Acoma, Adoption, Adornment, Agency System, Agriculture, Anatomy, Antiquity, Architecture, Arrows, Bows & Quivers, Art, Atlantis, Axes, etc.

The first volume embraces the letters A to M inclusive.

A. HRDLICKA.

Games of the North American Indians.—In a large volume¹ Stewart Culin presents "a classified and illustrated list of practically all the American Indian gaming implements in American and European museums, together with a more or less exhaustive summary of the entire literature of the subject." The many amusements of Indian children, such as "tag," which are played without implements are not within the scope of his compilation, and dolls are not included. None of the games described as Indian were imported into America; on the other hand "we have taken their lacrosse in the north, and racket in the south, and the Mexicans on the Rio Grande play all the old Indian games under Spanish names." Certain games, however, strikingly resemble those of the Europeans, and with various modifications the same game is played throughout the continent, by tribes belonging to unrelated linguistic stocks.

¹ Culin, Stewart. Games of the North American Indians. *Bur. of Amer. Ethn.*, 24th Ann. Rep., Washington, 1907. pp. 1-846, 1112 figs., 21 pls.

Games of chance are described first. Dice in the form of banded sticks, plum stones, small bones, or ivory figures of birds or mammals (which count for the player whom they face after being thrown) were widely used. A second class of games of chance includes those in which a small stone or other object is hidden in moccasins or under wooden cups, suggesting the illicit "shell game." Forfeits ranged from arrows to horses, and the games were sometimes played far into the night.

Games of skill include archery, various ball games in some of which racing is involved, and the game of sliding darts along the hard ground or ice toward a mark. Like the dice game, *hoop and pole* with many variations was played throughout the continent north of Mexico. A hoop twined with a network like a spider's web was rolled along the ground and darts were thrown at it, the count being determined by the hole penetrated. It was played by men only, but the lighter game of *ring and pin* was played also by women and girls. A perforated or penetrable object, such as a rodent's skull, attached to a cord was swung in the air and caught upon a pin or dart fastened to the other end of the cord. The most elaborate of the games of skill is that which resembles lacrosse. It was sometimes played between the young men of different villages, there being thirty or more players on a side. Among the many training regulations there is one which forbids the eating of hares since they are timid creatures. Ceremonial dances precede the game; each side has its conjurer and the spectators are numerous. The players are dressed only in girdles and ornamental tails of hair or feathers. They are armed only with rackets but in the scrimmages of the game bones are occasionally broken.

"Games of pure skill and calculation such as chess are entirely absent." The minor amusements, briefly described in this volume, include whip tops, cat's cradles, bull roarers, swings, stilts, and others. The author concludes that the games are "instruments of rites or have descended from ceremonial observances of a religious character." The myths with which they are associated are as widespread as the corresponding games, which are not only for amusement but to drive away sickness and avert evil. The book is admirably arranged for reference. With the picture of each implement there is generally a vivid account of its use by an eye-witness. The author has written only the necessary introductory passages and summarizes the conclusions of his eight hundred pages in eighteen lines.

F. T. L.

ZOOLOGY

Oogenesis in Insects.—It is a much debated question whether the sex or germ cells are set apart at the outset of embryonic development or arise later by modification of certain of the somatic or body cells. The continuation of Marshall's studies on the anatomy and embryology of the wasp *Polistes pallipes*¹ treats of the early history of the cellular elements of the ovary. The author finds that in the embryos and very early larvæ, each undifferentiated ovary is a syncytium with a number of nuclei similar in structure. In the course of development oocytes, primitive nurse-cells, and follicular epithelial cells are developed from the undifferentiated cells of the distal end of the egg tube. In a similar study of a Phryganid² he found that the first differentiation had taken place in a fairly old larva. At this stage the cells may be either "1st, undifferentiated or, 2d, passing through the first stages in the development which is to result in the further differentiation of oocytes or nurse-cells. Cells of the first group may either remain unchanged and become the epithelial cells or they may pass through the same stages as those of group two." Thus Marshall believes that the sex cells arise late and have a common origin with certain other cells in the ovary.

These results agree essentially with those of the earlier workers, notably Korschelt, '86, on the history of the germ cells of insects, but are in sharp contrast to the results of Heymons '95, Lecaillon '00-01, and many other recent workers who contend that the germ cells are in origin perfectly distinct from the follicular epithelium.

W. A. RILEY.

Parthenogenesis of *Bacillus rossii*.—The theory that each body cell contained both male and female constituents, and that the egg cell in becoming mature gave off its male elements in the second polar body has also been much discussed. This idea was supported by finding that the second polar body was not given off from certain eggs which

¹ Marshall, Wm. S. '07. Contributions towards the embryology and anatomy of *Polistes pallipes*. II. The early history of the cellular elements of the ovary. *Zeitschr. wiss. Zool.* lxxxv; pp. 173-213, pls. 12-14.

² The early history of the cellular elements of the ovary of a Phryganid, *Platyphylax designatus* Walk. I. c. pp. 214-237, pls. 15-16.

developed parthenogenetically. According to Baehr,¹ the walking stick *Bacillus rossii* must be added to the list of parthenogenetic species in the development of which the second polar body is formed, and the first divides in two. There is no evidence of their functioning further for they apparently degenerate and disappear.

Contrary to a generally accepted belief that parthenogenesis in this species quickly leads to degeneration, the author reared perfectly healthy females from at least the ninth parthenogenetic generation. Apparently only females are produced,—it is a case of normal thelytoky.

W. A. R.

Phagocytosis.—By means of a clever technique Mercier² has been able to throw new light upon the much debated question as to the nature of the phagocytes in the batrachians and the insects. On injecting sterilized, powdered carmine before the beginning of metamorphosis he found that it was taken up by the leucocytes and that leucocytes thus marked were yet capable of phagocytosis. Through this method he was able to demonstrate beyond a doubt the active participation of the leucocytes in the degeneration of the muscle fibers. In the case of the batrachians the muscles exhibited signs of degeneration at the time that the leucocytes entered but in the case of the fly *Calliphora* such signs were not to be detected microscopically. The fiber becomes broken up into sarcocytes which are engulfed by the phagocytes. There is no such phenomenon as the formation of myoclasts and consequent autophagocytosis. The author was able to demonstrate with equal clearness the active participation of the leucocytes in the destruction of the fat body of *Calliphora* and to distinguish them from the so-called "pseudonuclei" of Berlese.

W. A. R.

Histolysis in Queen Ants.—Janet³ has studied in queen ants, the degeneration of the wing muscles, which begins very soon after the

¹ Baehr, W. B. v. '07. Über die Zahl der Richtungskörper in parthenogenetisch sich entwickelnden Eiern von *Bacillus rossii*. Zool. Jahrb. Anat. xxiv pp. 174-192. Pl. 16.

² Mercier, L. '06. Les processus phagocytaires pendant la métamorphose des batraciens anoures et des insectes. Arch. Zool. exp. et gen., 4e ser., t. v. pp. 1-151, pls. 1-4.

³ Janet, Ch. Histolyse, sans phagocytose, des muscles vibrateurs du vol, chez les reines des Fourmis. C. R. Acad. Sci. Paris. cxliv, 1907, pp. 393-196.

nuptial flight. This histolysis does not begin simultaneously or advance with equal rapidity in all of these muscles and hence among fascicles apparently intact may be found those in which the degeneration is in various degrees of completeness or even terminated. Janet states that throughout the process there is no phagocytosis, or ingesting of solid particles by leucocytes. The wing muscles are finally completely replaced by adipocytes which, he believes, arise from leucocytes.

W. A. R.

Notes on Entomological Literature.—*The Green Pigment of Locustidae.*—Podiapsky¹ has studied both the chemical and the spectroscopic peculiarities of the green pigment extracted from the wings of *Locusta viridissima*. He was able to separate a yellow and a green pigment completely parallel to, if not identical with, the xanthophyll and the chlorophyllan of plant-green. The paper is very suggestive as regards methods.

W. A. R.

Inner Metamorphosis of the Trichoptera.—Much as the caddis flies have been studied from the biological and the systematic view point, comparatively little is known regarding their histologic structure, and practically nothing concerning their inner metamorphosis. Lubben's extended contribution² is therefore especially welcome. The author discusses the changes in the respiratory system, the sexual organs, and the alimentary canal. The work has not been limited to a single species but treats of a wide series and brings together many interesting details.

W. A. R.

Starving out the Codling Moth.—Under this caption Fabian Garcia of the New Mexico Agricultural Experiment Station issues a call to fruit growers to exterminate the codling moth in a single season! The late frosts of last April left little pome fruit in the territory: if fruit growers will but cooperate in the destruction of what little remains (which will all be worthless anyway because all will be wormy) and will destroy also all wild rosaceous fruit and walnuts, the codling moth, being deprived of its food, will be eradicated. The optimism

¹ Podiapsky, P. '07. Über das grüne Pigment bei Locustiden. Zool. Anz. xxxi pp. 362-366.

² Lubben, H. '07. Über die innere Metamorphose der Trichopteren. Zool. Jahrb. Anat. xxiv, pp. 71-128, pls. 11-13.

of the plan, its faith in the applicability of laboratory results by the public, undaunted by the contemplation of the inertia of the human species, is delightful.

J. G. N.

Fossil Insects.—The four parts of Handlirsch's *Die Fossile Insekten*¹ now at hand (640 pages and 36 double plates) suffice to show that this is a work of first importance to every student of fossil insects. In bringing together and making accessible descriptions and figures of practically all the known fossils (at least, in the older strata, thus far treated), and in correlating the fragmentary knowledge of them with keen morphological insight, the author is rendering good service. Though not all his more radical changes in groupings are likely to prove acceptable, and though the multiplicity of new groups of all grades will seem at first confusing, all will agree that the collective result of the work is substantial progress. Hitherto few monographers of insect orders have noticed the fossil representatives of the orders. There will be less excuse for the neglect of the paleontological evidence in the future.

J. G. N.

A Catalogue that is in part a Monograph.—The sons of the late Baron de Selys Longchamps of Liege are building a worthy monument to the memory of their father in the issuance of a catalogue of his zoological collections. The first number that comes to hand (Fascicle xvii, *Cordulines*, by M. R. Martin) shows that this, for the Odonata at least, is to be a great monograph. This small subfamily of dragonflies containing fewer than 140 species, is described on 94 quarto pages, illustrated by 99 (mostly multiple) text figures and three colored plates. The text figures are admirably executed and are sufficient for all practical purposes. The colored plates add little of real value, although they greatly increase the cost of the work. To every special student of the dragon-flies, this work will be indispensable because of its comprehensive character and its general excellence.

J. G. N.

¹ Handlirsch, A. *Die Fossile Insekten, und die Phylogenie der rezenten Formen.* Leipzig. Wilh. Engelmann.

Berlese's Entomology.—Fascicles 21-22 (pp. 585-648) of Berlese's magnificent work¹ are just at hand. They conclude the discussion of the nervous system and begin that of the organs of special sense. Like the preceding fascicles these are not mere compilations but are rich in new facts for the student of insect morphology.

W. A. R.

BOTANY

The Fungi of Termite Nests.—We are accustomed to think of Belt's classic observations on the leaf cutting ants of South America as the beginning of our knowledge of the relationships between ants and fungi, but Petch² assures us that Sweathman in 1781, nearly a century before Belt's discoveries, stated that in tropical Africa some species of termites had chambers in their nests in which grew a kind of fungus used by the ants as food. Although the "fungus gardens" of the true ants of tropical America have been quite fully described, we have had until the present time no comprehensive treatment of the similar habits in the termites of the Eastern Hemisphere. Petch brings together and tests by his own extensive studies of the Ceylonese species, the scattered observations on this subject.

Ceylon does not afford such variety of form and size of termites as Australia and Africa, but the nests of *Termites redmanni* and *T. obscuriceps*, the only two species which Petch studied, are abundant everywhere except in the highest districts. The ant hills, roughly conical in form, are only about six feet high. Their upper portion is continued into one or more hollow conical structures called chimneys. The form of the nests varies greatly; they may slope gradually to the top of the chimneys, they may branch into several chimneys or they may have a solid apex and bear the chimneys at the side. They are built of earth and grains of sand brought up from the interior of the nest and cemented together by a secretion of the termites. A large portion of every nest is underground. In the early stages of development the presence of a nest is usually indicated by three or four chim-

¹ Berlese, A. Gli insetti, loro organizzazione, sviluppo, abitudini e rapporte coll. uomo. vol. 1. Milan. Società Editrice Libraria.

² Petch, T. The Fungi of Certain Termite Nests. *Ann. Roy. Bot. Gard. Peradeniya*, 3: 185-270, pl. 5-21. 1906.

neys 10-20 cm. high, surrounded by the scattered earth brought up in excavating the underground chambers. In fact in some cases the nest is entirely under ground and the chimneys are wanting. Reasons for the differences have not been found.

Internally the nest is composed of numerous chambers roughly oval in shape, 5-25 cm. in diameter and 5-15 cm. in height, connected by numerous galleries sometimes as much as 1 cm. in diameter but generally only large enough to permit of the passage of two or three insects at once. Similar galleries connect the chambers with the chimney. For a discussion of the purposes of this structure the original paper must be consulted. Some idea of the extent of the underground system of these nests may be gained from experiments which Petch made; in one case water was run in for two hours from a pipe delivering 15 gallons per minute but this was quite fruitless so far as filling the opening was concerned.

The chambers, except the royal cell, are generally nearly filled with a structure designated as the comb. This is a grayish or brownish mass, traversed in all directions by a labyrinth of anastomosing galleries, and closely resembling in general appearance a coarse bath sponge. The combs lie free in the chambers, leaving a clear space of 2 to 3 cm. between them and the roof and the sides. The comb substance is built up of closely packed balls of about 0.75 mm. in diameter, composed of finely divided vegetable substance. Under the microscope irregular pieces of ringed and pitted vessels, up to 250 microns in length, may be seen, as well as tracheids, sclerenchymatous cells, and the hyphae and spores of *Halminthosporium*, *Diplodia*, etc., all imbedded in a ground substance from which all structural detail has disappeared. The fact that the same substance is found in the intestines of the workers and soldiers, taken in connection with the regularity of formation of the comb from the small pellets, shows that this is made up of the excreta of the termites. It will thus be seen that the comb itself is not of fungus origin.

The surface of the comb is given a grayish or glaucous appearance by the presence of a thickly woven mat of fungus hyphae. From this mass of hyphae small stalked spheres arise by the combination of several threads into an upright stalk; these hyphae branch repeatedly above and finally give rise to conidia. These are the "conidial formations" which have been described by all students of the fungi of termite nests. Injured spheres or stalks from which the conidia have fallen are never found on the comb, and it would seem that the termites in eating them must consume them at a single bite.

Some have suggested that this fungus is one which is found in the neighborhood of the nests on decaying wood and that it is introduced into the nest accidentally by the termites, but in an extensive investigation of the fungi of Ceylon in which large quantities of dead wood passed through his hands, Petch was never able to find any form at all similar to that in the nests.

Occasionally an agaric also develops from the comb. This species is the chief edible form of Ceylon and so generally is it esteemed that it is difficult to obtain perfect specimens, for the natives who collect them for food do not secure the long stipe intact and unfortunately they do not overlook many examples. This fungus has never been found growing from the hill itself but is always produced from the underground portions of the nest. The comb from which it develops may be as much as four feet underground but the most of Petch's specimens were found to grow from combs nearer the surface. The connection of the agaric with the hyphae described above has not been demonstrated. Efforts to germinate the spores or to grow the sphere-producing mycelium from the tissue of the agaric have proven unsuccessful. It is not improbable, however, that they are stages of the same species. At first the agaric forms brownish-white, somewhat conical, tomentose columns 3 to 5 mm. in diameter and 1 to 2 cm. in height; in some cases Petch found as many as fifty of these on a single comb. All the developing agarics reach this stage but only one forms a *Pluteus*; the others cease growth before they reach the roof of the chamber and it has been found impossible to cause them to develop farther by experimental methods. This peculiarity of the species renders it almost impossible to obtain other than the mature and the very earliest stages. It has not been found possible to cause a normal comb to produce the agaric by artificial treatment, and after it has borne one, another will not be produced. No results have ever been obtained by digging in the nests at random in search of the intermediate stages; when the mature fruiting body has appeared on the surface no more may be expected from the same comb and it does not indicate that the other combs of the same nest are in a state in which they may be expected to produce agarics. The termites have been known to consume the stipe up to the surface of the ground and then to stop the opening. This agaric has been assigned to several genera, *Lentinus*, *Collybia*, *Pluteus*, *Pholiota*, and *Flammula*; Petch considers it a modified *Volvaria*. It has never been found when it could not be traced to the termite nests.

A second agaric seems sometimes to develop from the termite comb,

but probably only in wet weather. In this species a number of stipes may develop from the same comb.

If a piece of fresh comb be removed from the nest and placed under a bell jar the spheres will decay if the insects have been removed but both spheres and external hyphae will be eaten if the termites remain. In the course of two or three days after the surface of the comb has been freed from these, small groups of erect hyphae, indistinguishable from those which give rise to the agaric, but apparently derived from the interior of the comb-substance, appear and grow rapidly into tall thin structures resembling the conidial forms of *Xylaria*. Petch has carried on a large series of cultural experiments with this form and concludes that it is probably *X. nigripes*. The termites eat this too as it develops. After continued rain *X. nigripes* grows from deserted nests.

Besides these forms, *Mucor*, *Thamnidium*, *Cephalosporium*, and *Peziza* sometimes grow on combs removed from the nests. Since none of these are found in the nests, though some of them are capable of growing underground, it seems probable that the insects "weed out" undesirable fungi as they develop.

Although it is known that the termites will eat the fungi it is not definitely proved that they form the food of the insects. The two species studied prefer fungi, or wood which has been attacked by fungi. Whether a difference in food is a factor in the differentiation of the termites into workers, soldiers and sexed insects is not decided.

The author observes that the mycelium of *Entoloma microcarpum* is composed of spheres of swollen cells which in detail resemble the termite spheres but are not so highly developed. He thinks that the spheres of the termite nests and the "Kohlrabihäufchen" of the leaf-cutting ants investigated by Möller are parts of a normal mycelium and that their form has been little, if at all, modified by the insects.

J. ARTHUR HARRIS.

The Longleaf Pine.—Schwarz's *The Longleaf Pine*¹ is an attractive little volume, describing in a popular style the silvics of *Pinus palustris*, the valuable hard pine of the Southern States. The subject matter is considered under nine main headings which cover the character of the virgin forests of this tree and their natural rotation, the tolerance of the species, its relation to injuries by fire, insects, cattle, and swine, its rate of growth, and its technical forest management.

¹ Schwarz, G. Frederick. *The Longleaf Pine in Virgin Forest, a Silvical Study.* New York, John Wiley & Sons, 1907. 12mo, xii+135 pp., illustr.

The longleaf pine is characteristic of the so called Southern Pine Forest, and occurs principally in a belt some 125 miles broad, from Virginia south and west along the coast to within a short distance of the Mississippi River, and in southeastern Texas. The chief type is that of a pure forest. Owing to various destructive causes, these forests are largely in groups of different ages. A second, mixed type is found farther inland, and is largely determined by differences in the composition of the soil. Here the longleaf pines occur on the hilltops while farther down, on the richer or damper slopes are the oaks, hickories, and other deciduous species, with shortleaf and loblolly pines.

The natural course of evolution of the longleaf pine forest and its method of reproduction are briefly sketched. The species is intolerant of shade and requires direct overhead light, since the dense terminal clusters of leaves shade the buds from side light.

The chief danger to which the southern forests are subject, is doubtless fire, hence this is treated at considerable length. The fires in longleaf pine forests are exclusively surface fires, which not only destroy the young seedlings in the grass, but injure the butts of the older trees, causing often considerable damage. The frequency of fires, set either accidentally or purposely for burning over grass lands, makes imperative the employment of rangers and the construction of fire lanes about commercial forests. As a rule, seedlings of one or two years' growth are destroyed by surface fires, but older plants usually escape total destruction by virtue of their thick bark and the dense head of long needles that not only protect the terminal bud but form a miniature fire screen by hanging down about the short stem to the ground. Frequent fires will, however, kill even these older seedlings, to say nothing of their destructive action on the humus.

The future silvicultural treatment of these forests is considered in Chapter 8. The forest must be perpetuated as well as exploited. Cutting to a diameter limit of 16 inches has been recommended. In some cases, a method of clear cutting with reserve trees left for seeding the cut over area will probably be found good. The aim of future management will also be partly to bring these forests into a more uniform condition instead of their present great irregularity.

Although more extended tables as to rates of growth and volumes might have been added, this little book will no doubt serve its purpose in helping the lumberman and the general reader to a better understanding of the proper study and treatment of our southern pine forests. The volume is handsomely printed and fully illustrated.

G. M. ALLEN.

Purple-producing Bacteria.¹—The Purpurbacteria² make an interesting group with certain characteristics differing from the majority of these plants. Many bacteria, in fact most of them, grow best in the absence of light, but the group of the Purpurbacteria grow best or as well in its presence. Most pigment-producing bacteria show color production best or only in the free access of oxygen — the group under consideration have the opposite characteristic that they produce their color best or only in the absence or in a diminished supply of oxygen. The color of most bacteria is outside of the cell, but with this group it is in the bacterial cell for the most part.

The author has brought together the known facts in regard to this group, has added some new methods of cultivation, and has contributed descriptions of a number of new varieties isolated by himself. He has furthermore studied more fully the action of light and other conditions on their growth and pigment-producing powers, so that the physiological characteristics of the group are clearly presented in detail. The plates include two of photomicrographs of some of the new varieties described in the text, a presentation of the appearance of bacteriopurpurin crystals from one of them, the color scheme of bacteriochlorin and bacteriopurpurin — the first in alcohol and the second in bisulphuret of carbon — and a number of absorption spectra of the pigments from different members of the group. The book is an interesting and important contribution to the study of the subject.

H. C. ERNST.

GEOLOGY

Rate of Recession of Niagara Falls.— Bulletin 306 of the United States Geological Survey, which has recently been issued,² is of much interest to the layman as well as to the student of geology. G. K. Gilbert traces the early development of the ideas that the falls are

¹ Die Purpurbakterien nach neuen untersuchungen. Eine mikrobiologische studie von Prof. Dr. Hans Molisch: Direktor des pflanzenphysiologischen institutes der K. K. Deutschen Universität in Prag. Mit 4 tafeln. Jena, Verlag von Gustav Fischer. 1907. pp. vii, 95, Octavo.

² Gilbert, W. K. and Hall, W. C. Rate of Recession of Niagara Falls (by G. K. Gilbert) accompanied by a report on the survey of the crest (by W. Carvel Hall). *Bull. U. S. Geol. Sur.* No. 306, 1907. pp. 1-31, 11 plates, 8 figures.

receding upstream, that the gorge below the falls is the result of this recession, and that it would be possible, by sufficiently accurate observations, to determine the rate of recession. He then discusses the data upon which computations of the rate of recession must be based, consisting of surveys of the crest-line of the falls made in 1842, 1875, 1886, 1890, and in 1905; and camera-lucida sketches made in 1827. After considering the relative accuracy of the different surveys and sketches, and plating the results together, the author concludes that a gradual recession of the Horseshoe Falls is demonstrated, while a much slower rate of recession is indicated for the American Falls. These changes are strikingly represented by contrasted photographs and sketches made from the same view-point, but many years apart.

Concerning quantitative results of the study, the author points out that the available data may be treated in a variety of ways, and made to yield widely divergent results. The lack of harmony is due in part to inaccuracies in the surveys, some of which are unavoidable; and in part to the fact that the rate at which the limestone crest breaks away is necessarily irregular. Too much confidence should not, therefore, be placed in exact mathematical expressions of the rate of recession. In general, however, the evidence proves a recession of about 5 feet a year with a possible error of not more than 1 foot, for the Horseshoe Falls, in the sixty-three years from 1842 to 1905; and a recession of less than 3 inches a year for the American Falls, in the seventy-eight years from 1827 to 1905.

The time consumed in the total recession of the falls from their former position near Lewiston is not considered in this report, except that the author briefly notes some of the many variable factors which must be taken into account in estimating such time. A short report by W. Carvel Hall on the latest survey of the crest line of the falls is appended to the paper.

A sprinkling of "reformed" (one is tempted to say "deformed") spelling throughout the paper occasionally distracts the reader's attention from the matter itself to the manner in which it is presented.

D. W. JOHNSON.

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